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Questions and Answers
For AUTOMOBILE STUDENTS and MECHANICS

A book of Self-Instruction for Automobile Students and Mechanics, as well as for all those interested in Motoring.

—BY—

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1911
The Charles C. Thompson Co.
Chicago, Ill.

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PREFACE

The Questions and Answers in this book will be found useful by every student and mechanic of motor cars and motoring, as a handy means of reviewing systematic study or in daily work.

It has long been recognized that the Question-and-Answer method is most effective in fixing in the memory facts gained by study or problems that confront the mechanic in his daily work; hence it is adopted for the purpose.

The more important subjects connected with motor cars, are treated individually, there being a separate set of Questions and Answers for each. For the greater convenience of the reader, the Questions and the Answers in each set appear on separate pages; the Questions can thus be used alone for self-instruction, while the Answers if needed are close at hand for reference.

Minor subjects are covered in a special catechism, which deals with all the factors which go to make up the power plant of a modern motor car.

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STUDY HELPS.

Questions for Review.

No. I.—MOTOR CARS.

1. What are the characteristic features of a motor car?
2. Name the principal types of motor vehicles.
3. What are the essential parts of a gasolene car?
4. How is the body attached to the car?
5. What is understood by the "power plant"?
6. Where is the engine generally situated?
7. What is a chassis?
8. How is the power generated in a gasolene motor?
9. How is the power transmitted?
10. How is the speed changed and checked?
11. What is meant by chain drive and gear drive?
12. How is an automobile controlled?
13. Describe the operating mechanism.
14. How many cylinders are used in automobile engines?
15. What is a starting handle and what is its function?
16. What is the general purpose of the clutch?
17. What becomes of the exhaust gases?
18. What is the function of a differential gear?
19. What is a carbureter?
20. What is an ignition system?
21. How is a motor car steered?
22. What are the essential parts of an electric car?
23. Name some of the advantages of electric vehicles.
24. Name some of their disadvantages.
25. What are the essential parts of a steam car?
26. What is the function of the generator?
27. Where is the generator usually carried on a car?
28. Name some advantages of the steam car.
29. What are its disadvantages?
30. How are motor trucks propelled?

STUDY HELPS.

Answers to Questions for Review.

I.—MOTOR CARS.

1. A motor car is a self-propelled vehicle driven by means of a motor borne on the vehicle. In American usage the term "automobile" is usually confined to carriages or passenger vehicles, while "motor car" is applied to all forms of self-propelling vehicles, whether for pleasure or commercial use.

2. Motor vehicles may be classified under four different types, according to the nature of the motive power, which may be (1) internal combustion engines; (2) steam engines; (3) electric motors supplied with current from a storage battery; (4) electric motors using current generated on the car by means of an internal combustion engine. Vehicles of the latter type are called "gasolene-electrics."

3. The complete gasolene car contains the following essential parts: The frame, the road wheels, the engine, the clutch, the transmission gear, the steering gear, the brakes, the ignition system, the carbureter, and the various controls of the engine and the car; also a body adapted to the purpose for which the car is to be used.

4. The body of a car is supported on springs attached to the frame and axles of the car.

5. The power plant includes the engine or motor, with its accessories, and the transmission gear, though the term is sometimes limited to include the engine or prime mover alone.

6. The engine of a gasolene car is generally carried in the front portion of the car, being attached to and supported by the frame, or is sometimes carried on a sub-frame, suspended from the frame proper.

7. The term "chassis," adopted from the French, strictly applies to the frame of a car, but as generally used by motorists it includes not only the frame, but also the wheels, springs, engine, gear, etc.—in fact, everything but the body.

8. The power is generated by the formation of an explosive hydrocarbon gas, which is sucked into the cylinder head by an outward stroke of the piston, then compressed by the return stroke, then ignited or fired, when it expands, and the expansion drives the piston outward again in a power stroke.

9. The power developed by the expansion of the gases after combustion is transmitted from the piston through a connecting rod to the crankshaft, which revolves a flywheel the motion of which is taken up by means of a clutch connected with the rear or driving axle by what is known as the transmission gear.

10. The speed may be changed by the operation of variable gearings, and is checked by the use of brakes. The change speed gear usually provides for two, three or four speeds forward and reverse.

11. In chain-driven automobiles the power is transmitted to the road-wheels by means of sprocket wheels and a chain or chains running to sprockets on the rear or driving axle. In gear-driven systems the power is usually transmitted by a propeller shaft to a system of bevel gearing on the rear axle and then communicated to the road-wheels.

12. There are two systems of control. The operation of the engine is controlled by regulation of the quality or quantity of explosive gas admitted to the combustion chamber, and by a governor. The movements of the car are controlled by the clutch pedal, change speed lever or levers, brakes and steering gear.

13. The control mechanism of a modern automobile includes the steering wheel, placed on top of a hollow shaft which operates the steering mechanism attached to the front axle. A spark lever and hand throttle lever are situated on

top of the steering wheel and respectively control the ignition and the supply of gas. The foot throttle, or pedal operated by the right foot, is used to throw open the throttle wide and overcome the action of the governor, thus causing the engine to work at full speed. A clutch pedal controls the operation of the clutch. A gear shift lever is placed so as to be operated conveniently by the right hand, and the various speeds may be obtained by placing this lever in different positions in the retaining device known as the quadrant. The brake levers—hand and foot—complete the operating mechanism of the ordinary car.

14. Motor cars are successfully operated with engines having from one to eight cylinders. Two are common on small cars, four is an average number, and many modern cars are equipped with six.

15. The starting handle is a crank connected with the end of the crankshaft and protruding in front of the car. When the handle is turned, the crankshaft revolves and the piston is moved in the cylinder so as to draw in, by its suction, a charge of explosive gas, or mixture, and so start the engine.

16. The clutch is a movable coupling device for connecting the transmission gear with the engine or flywheel, so that the power generated by the engine may be communicated to the road-wheels. It thus forms part of the transmission system. It is withdrawn to disconnect the engine when stopping or running down hill, etc., and is usually operated by means of a pedal.

17. The exhaust gases or products of combustion are drawn from the cylinder head by the return stroke of the piston after the power stroke, and pass out through an exhaust valve into a pipe leading usually to the muffler—a device for silencing the noise of the exhaust—and thence to the open air.

18. The differential gear, also called balance or compensating gear, is the very necessary device which enables the driving wheels of an automobile to turn at the different

speeds required when turning corners. Differential gears are usually situated in the hollow shaft of a live axle and consist of a train of wheels connecting the transmission shafting that brings the power from the engine with the two members of the driving axle which turn the road-wheels.

19. The carbureter is an apparatus used to transform the liquid fuel, generally gasolene, into a gas, and at the same time mix it with such a proportion of air as will make it combustible and capable of being ignited or fired to generate power in the engine.

20. In every internal combustion engine there must be some arrangement by which the explosive mixture is fired at the proper time to generate power; that is, when the piston is at or near the top of its return stroke. In most modern automobiles the firing is accomplished by means of an intermittent electric spark, which is caused to appear in the cylinder head at the proper moment, and of sufficient heat to ignite the charge. The devices by which this spark is secured and accurately timed constitute what is known as an ignition system.

21. The steering gear of a self-propelled vehicle is necessarily different from that of horse-driven carriages in which the front axle is pivoted at the center. In modern construction a device known as the Ackermann "short axle system" is employed to obtain the correct deflection of the wheels when describing a curve. These steering gears are designed on the principle that if the direction of the steering axes be produced they should meet in the line of the rear axle produced.

It is necessary that the steering of an automobile be steady, and in order to obtain this steadiness some device must be employed which is not affected by the inequalities of road surface. This is secured in motor car practice by employing a worm gear for operating the steering arms attached to the axles of the front wheels. The irreversibility of the worm gear provides against shock being carried back to the driver, while at the same time the screw action of the worm pro-

vides a powerful control over the direction of the wheels. The worm gearing is operated by means of a steering wheel on top of a pillar connected to the gear.

22. The type of motor car known as the electric car depends for its motive power on electrical energy, either stored or generated on the car. Its characteristic parts are a battery of storage cells, which can be recharged, when exhausted, at any convenient charging station; a dynamo, used either for generating current to run the car direct or to be stored as energy in the battery and used as required; an electric motor, and the necessary controlling apparatus. The usual type of electric vehicle is one in which the storage battery is employed to drive the motor. In another type, an internal combustion engine is used to drive a dynamo, the current for which is passed to an electric motor or motors, which drive the road-wheels.

23. Some of the advantages of the electric motor for automobile propulsion are as follows:

(1) Extreme simplicity of parts—motor, controller and battery—with consequent ease of finding faults and ease of measuring power used.

(2) Ease of manipulation and flexibility of control; reverse for all speeds, etc.

(3) Cheap lubrication and absence of lubrication troubles, valve troubles, dirt, smell, etc.

(4) Certainty and ease of starting from the driver's seat, by a switch only.

(5) No exhaust noises, smell, back-fire or muffler explosions.

(6) Cheap and clean housing, absence of inflammable material in store, and hence little fire risk compared to gasolene risks.

24. The disadvantages of electric cars include the great weight of batteries required to be carried on the car; limited range of travel; loss of time for recharging; rapid depreciation of batteries, and initial cost of batteries, which latter out-

weighs the cheapness of electric motors and the cheapness of mechanical equipment.

25. The essential parts of a steam car are the boiler, or, more properly, the generator, which, in the case of the White steamer, for example, consists of helical coils of steel tubing placed one above the other and surrounded by a casing of insulated material; a burner for the liquid fuel which fires the boiler; a large water tank to supply the boiler, and a condenser or radiator in which the exhaust steam is condensed into water for further use in the generator. The drive is the same, or practically the same, as on a gasolene car, but there is no change speed gear and no clutch, the speed being practically governed by the throttle. No reverse gear is necessary in the usual meaning of the term, the valve motion of the engine being so arranged that the engine will reverse itself.

26. The generator, or boiler, of a steam car is used to convert water into steam for the operation of the engine, the water being used over and over again through the medium of a condenser. In the White steam car the water is turned into steam as it circulates through the coils of the generator. An automatic valve regulates the fuel supply in exact proportion to the water admitted to the boiler. It is regulated by the engine so that however much steam the engine is taking, the heat and the amount of water admitted will be in just the right proportion to supply constant pressure of steam.

27. The generator, or boiler, is usually placed immediately in the middle of the chassis of the car, directly under the front seats.

28. The great advantages of the steam car, of whatever type, are its almost perfect silence in running and the very great reduction in vibration, the balance of the steam engine being considerably better than that of the gasolene engine, while the driving effort on the crank is almost constant. For this reason the transmission is particularly light on the tires, and with the double-cylindered engine there is practically no necessity for a heavy flywheel. It has a great range of power, easily controlled, and is easily restarted.

29. The disadvantages of the steam car may be stated as follows: Limited number of makes to select from; delay in first starting; close attention required to indicators, and frequently visible exhaust. These disadvantages have interfered with the lighter type of steam car, but the heavier type—closely approaching the gasolene car in general appearance—has a large following.

30. Motor trucks or "commercial cars" are usually propelled by electric motors supplied with current by storage batteries, or they may be "gasolene-electrics," that is, a combination of the gasolene engine and the electric motor is used—the gasolene engine being used to drive an electric generator which in turn furnishes current to electric motors that drive the road-wheels. Many light commercial cars and public service cars are also operated by gasolene engines alone.

STUDY HELPS.

Questions for Review.

No. II.—ENGINES.

1. What kinds of engines are used for propelling automobiles?
2. What term best describes the gasolene engine or motor?
3. What is the principle of its operation based on?
4. What is the motive power?
5. What is the great advantage of the gasolene engine for motor car use?
6. What is the nature of the fuel used in an internal combustion engine?
7. How is the gas produced and drawn into the cylinder?
8. How is the engine started?
9. How is the gas ignited?
10. Describe the cycle of operations in a gasolene engine.
11. What is a two-cycle engine?
12. What is the function of the inlet valve?
13. Where is it situated?
14. What is the function of the exhaust valve?
15. Where is it situated?
16. How are the exhaust gases disposed of?
17. What is the function of a crankshaft?
18. What is the function of a flywheel?
19. How is the flywheel fixed to the crankshaft?
20. What are piston rings?
21. What is the function of a camshaft?
22. How is the cylinder cooled?
23. How many cylinders are generally used in a gasolene engine?
24. How is the engine lubricated?
25. What is a radiator in motor car practice?
26. How is the firing sequence of the cylinders in multi-cylinder engines controlled?

27. What is the form of the cylinder used in a gasolene engine?
28. What is the two-to-one shaft?
29. What is the combustion chamber?
30. What is meant by "mixture"?
31. What is a "back fire"?
32. What is the object of the compression stroke?
33. How often is the cycle of operations repeated in a given time?
34. What precautions must be observed in the use of gasolene?
35. What type of carbureter is generally used?
36. How is the nature of the mixture controlled?
37. What are the advantages of multi-cylindered engines?
38. What is the connecting rod?
39. What is the crank case?
40. What is the usual form of the inlet and exhaust valves?
41. What is meant by a mechanically operated valve?

STUDY HELPS.

Answers to Questions for Review.

II.—ENGINES.

1. The engines used for propelling automobiles are, in a great majority of cases, gasolene motors; the notable exceptions are in the case of steam cars and electric cars, using respectively steam engines and electric motors.

2. The term which best describes the gasolene engine or motor with which most automobilists have to do is "internal combustion engine." It is also often called an "explosion engine," but this term does not correctly describe it.

3. The principle of operation is based on the well known facts that gasolene vapor, or a fine spray of gasolene, mixed with air forms a highly inflammable mixture, and that if this mixture be confined in a closed chamber and ignited by a flame or spark, it will explode and expand.

4. The expansion of the ignited charge of inflammable mixture is utilized as the motive power in a gasolene engine.

5. The great advantage of the internal combustion engine for motor-car use is that, the fuel used being burned or consumed inside the engine itself, it forms a very simple and satisfactory way of producing power for driving the road-wheels. The gasolene engine—power for power—is much lighter than any form of steam engine, and the boiler is capable of running long distances without replenishing the supplies, an all-important consideration in automobiling.

6. Various kinds of fuel can be used in internal combustion engines, but all of them are hydrocarbons, and in a great majority of cases the very light hydrocarbon known as gasolene or petroleum spirit is used. From this the gas is produced which is burned inside the engine.

7. The production of the gas from the hydrocarbon fuel

is usually performed by means of a carbureter. It is drawn into the cylinder through the suction of the engine, the downward stroke of the piston tending to create a vacuum in the cylinder head and thereby causing suction through the inlet port.

8. In starting the engine the initial charge of explosive gas, or mixture, must be drawn into the cylinder by operating the engine by hand, through the starting handle in front of the car, or by means of one of the various self-starting devices fitted to many modern cars and operated from the driver's seat.

9. Some method of igniting the gas so as to cause it to expand and develop power must be provided, and this is usually attained by means of an electric spark caused to appear inside the combustion chamber at the moment when the charge is ready for ignition. The methods of producing this spark at the proper time are numerous and varied. Generally speaking, in modern practice two classes of ignition are employed, namely, a battery and coil or a magneto.

10. Most gasolene engines are of what is known as the four-cycle type; that is, the engine has four different duties to perform, the sequence of operations being as follows: First, inlet or induction by the drawing in of the gas. Second, compression of the gas in the cylinder in order to use its expansive force to better advantage. Third, firing or igniting the compressed charge, which by expanding brings pressure to bear on the piston head, and forces it downward to do work in revolving the crank shaft. Fourth, exhaust gases, or the residuum of the burnt gas, must be ejected from the cylinder. These four operations having to be performed in sequence, as steps in the cycle of the engine, the gasolene motor, as used in most automobiles, is known as a four-cycle engine. On their completion all the parts are in the same state as at the beginning, and the cycle of operations is repeated time after time as long as the engine is kept at work. The cycle includes two outward and two inward strokes of the piston, or four strokes in all, so that the flywheel is revolved twice

during each complete cycle. The four successive strokes are called the suction stroke, compression stroke, working stroke and exhaust stroke, respectively.

11. In two-cycle engines the suction, compression, working and exhaust strokes all occur during one revolution of the flywheel, instead of during two revolutions as in the four-cycle engine.

12. The function of the inlet valve is to admit the explosive gas to the cylinder at the proper time. It may be operated either by suction from the piston, closing with a spring, or by means of a cam or a half-speed shaft geared to the crankshaft.

13. It is situated on the carbureter side of the engine to open the inlet pipe which admits gas to the cylinder head.

14. The exhaust valve is the device by which the exhaust gases are permitted to escape from the cylinder head at the proper time after combustion, being driven out by the return or exhaust stroke of the piston.

15. The exhaust valve is situated sometimes on the opposite side of the engine from the carbureter, sometimes on the same side as the inlet valve, as when both the inlet and the exhaust valve are operated by means of a camshaft driven by the engine crankshaft, but at half its speed, so that each valve opens only once for each two revolutions of the crankshaft.

16. The exhaust gases, on being driven from the cylinder, pass into the exhaust pipe and thence usually to a muffler or exhaust box, by means of which they are cooled and silenced before passing to the outer air. Sometimes they are permitted to pass to the outer air direct without passing through the muffler, this being accomplished by what is called a "muffler cut-out." Sometimes they are utilized before their final escape in operating horns, whistles, etc.

17. The purpose of the crankshaft is to convert the reciprocating or up-and-down motion of the piston into rotary motion for transmission to the road-wheels. This is accomplished by means of a connecting rod and is illustrated by the

case of a bicycle. The bicycle is propelled by the up-and-down motion of the rider's legs which, like the connecting rod, press on the cranks, converting the up-and-down motion into a rotary one.

18. The flywheel is a heavy wheel fixed on the crankshaft and forming part of the crank. Being pivoted at its center, it tends to keep on revolving when once put in motion and its impetus carries the crank round at the end of the piston stroke and forces back the piston. One side of the flywheel is usually made thicker and heavier than the other to balance the weight of the crank and part of the connecting rod, the heavy part being opposite the crank. This construction is designed to prevent or to minimize the vibration of the engine.

19. The flywheel is usually keyed on to the crankshaft; that is, a key or piece of steel of square section fits into a groove in the crankshaft for half its depth, the other half fitting into a groove in the flywheel. The key is driven tight to lock the shaft and flywheel together. In small motors the end of the shaft is turned taper or conical in the lathe and the flywheel is bored to exactly the same taper. The wheel is then forced on and a key driven in to hold the two together. A nut at the end of the shaft prevents the flywheel from working loose.

20. Piston rings, so called, are three or sometimes four cast iron rings fitted in grooves around a piston to keep the latter tight in the cylinder and thus prevent the escape of the gases in the cylinder head, which would mean loss of power in the engine. The rings are turned to a slightly larger diameter than the cylinder and a small piece is cut out of them, leaving an opening in the ring of about a quarter of an inch. They can then be squeezed so that they will enter the cylinder. By their elasticity they press on the bore of the cylinder, and fitting in grooves turned in the piston they prevent the pressure from leaking past the piston.

21. The camshaft is a shaft fitted with cams or projections resembling long teeth in a cogwheel, which actuates the push-rods by means of which the inlet and exhaust valves are

opened, the camshaft making only one revolution to two of the crankshaft.

22. There are two systems of cooling the cylinders of an internal combustion engine, namely, by air or by water. In the first system, gills, fins, flanges or pins are cast round the cylinder and a circulation of air is maintained while the engine is running, partly by the motion of the car and often by means of a fan. In water-cooled systems, a water jacket is cast around the cylinder and is kept supplied with water which, when heated, is cooled by means of a radiator, etc.

23. Motor cars are fitted with engines having from one to six and occasionally eight cylinders. Small cars are successfully operated with one cylinder. Cars with two cylinders are common and the average touring car is of the four-cylinder variety. Six-cylinder engines are frequent on the larger, high-powered cars.

24. There are several methods of lubricating motor car engines. What is known as the splash system is common. In this the crank case contains a certain quantity of oil which becomes heated in the crank case, where the crankshaft and connecting rod dip into it, and by their rapid revolutions splash it round and up into the cylinder, lubricating the piston and piston pin. The oil supply is renewed in various ways, either by gravity feed or force feed, in the latter case by means of a pump, worked by the engine.

25. The radiator is a device employed in a water-cooling system on motor cars, for cooling the water after it leaves the cylinders. In principle it is a long pipe bent backward and forward, fixed in front of the car and so arranged that the heat from the hot pipes is taken up and the water cooled by the current of air the car meets in running. The water then circulates back to the cylinder jackets and so prevents overheating of the engine.

26. The firing sequence of the cylinders varies according to the individual ideas of the designer. It depends to a certain extent upon the angle at which the cranks of the crankshaft are set. This angle may be either 180 degrees, or the

cranks may be set together. If they are set together, an impulse occurs at every revolution, but in this case the cranks must be balanced to counteract the vibration. In fact the "balance" of the engine must be considered at all times.

27. The cylinder is a hollow casting bored for its length truly circular and parallel. This is termed the "bore" and in it the piston works gas-tight.

28. The two-to-one shaft is a camshaft, also called the half-time or half-speed shaft, geared to the crankshaft so as to revolve for every two revolutions of the crankshaft. It carries the cams for lifting the exhaust valves, etc.

29. The cylinder head, in which the hydrocarbon gas is compressed and then ignited or fired, is often called the combustion chamber.

30. "Mixture" is the term applied to the gaseous compound of atmospheric air and gasolene vapor which is sucked into the cylinder by the inlet stroke, then fired by the ignition system.

31. A "back fire" is a premature explosion in the cylinder and is usually caused by the gas being ignited before the piston is in a correct position for its working stroke, thus causing the piston to be driven in the reverse direction to that in which it should travel. Back fires generally take place in starting the motor when the spark is too far advanced, and must be carefully guarded against.

32. The compression stroke of the piston is important because of the nature of the gas, or mixture. The subsequent impulse is very much more powerful after ignition than it would be if the gas were not compressed. In other words, more power is developed in the engine.

33. The cycle of operations in gasolene engines is repeated very rapidly—about 200 to 250 times a minute on the average, and twice as often as that in some motorcycle engines.

34. In using gasolene all official regulations should be strictly observed. Gasolene is not explosive in its liquid form, but is highly inflammable, and no naked light should ever be

brought near it. Water is of no use in extinguishing the burning gasolene, and in case of gasolene catching fire, one of the special gasolene extinguishers should be used. Sand is sometimes effective.

35. The type of carbureter almost universally used on automobiles is the spray carbureter, in which the liquid gasolene is drawn through a nozzle or jet by the suction of the engine and leaves the jet in the form of spray which mixes at once with the air sucked into the carbureter at the same time.

36. The nature of the mixture supplied to the engine is controlled by regulating the flow of gasolene to the carbureter and the admission of air to the mixing chamber. The greater the proportion of gasolene, the richer the mixture and vice versa. The flow of both gasolene and air is regulated by means of valves.

37. Engines with more than a single cylinder are generally preferred because they reduce the force of the impulses and increase their frequency, resulting in less vibration and smoother running. This is, of course, better for the car as well as for the occupants. With several cylinders the turning force of the crankshaft is more regular and the reciprocating parts are better balanced, but of course the complication, weight and cost are all increased.

38. The connecting rod joins or couples the closed end of the piston with the crankshaft. It moves with the piston in the cylinder and converts its reciprocating motion into a rotary motion of the crankshaft.

39. The crankshaft is mounted on bearings in a casing called the crank case. This is usually made of aluminum alloy to secure lightness, and with bracket extensions it often forms a means of attaching the engine to the frame of the car. It also serves as an oil-bath into which the cranks dip as they rotate and splash the oil about so that they thoroughly lubricate the engine.

40. The usual form for both the inlet and the exhaust valves is a circular disk fitted with a stem, this type of valve

being called a mushroom valve and resembling a large flat-headed nail.

41. Valves operated by a cam on a half-speed shaft are usually called mechanically operated valves, and this is the form most often used in both the inlet and the exhaust valves, instead of having the inlet valve work automatically by the suction of the piston (closing by a spring), though some prefer the automatic valve for high-speed work.

STUDY HELPS.

Questions for Review.

No. III.—THE CARBURETER.

1. What is gasolene?
2. What are the chief parts of a gasolene motor?
3. What is a carbureter and what does its name imply?
4. What is the function of a carbureter?
5. What are the forms of carbureter in general use?
6. What form of carbureter is preferred in modern machines?
7. Describe a modern carbureter of preferred form.
8. Describe a surface carbureter.
9. Describe a spray carbureter.
10. What is an automatic carbureter?
11. What is a float in a carbureter?
12. What is the jet in a carbureter?
13. How is the flow of gasolene into a carbureter controlled?
14. What happens to the gasolene in the carbureter?
15. How is the air supply effected?
16. How is the air supply regulated?
17. What is "mixture"?
18. What is a rich mixture?
19. What is a poor mixture?
20. What is the right kind of mixture?
21. What happens to the mixture after it leaves the carbureter?
22. What is the combustion chamber?
23. By what force is the mixture drawn into the combustion chamber?
24. What is the nature of the mixture made by the carbureter?
25. How is the mixture fired?
26. Describe the relative importance of the carbureter in an internal combustion engine.

27. Name some possible troubles that may arise from defects in the carbureter.
28. How is the level of the gasolene in the carbureter kept constant?
29. What happens when too much gasolene passes through the spray nozzle?
30. How can the supply of gasolene to the engine be diminished?
31. How can the supply of gasolene to the engine be increased?
32. What does an unsuitable mixture result in?
33. Can you give an illustration of air drawing the fluid along with it?
34. What is the size of the opening in the jet of a carbureter?
35. Is not so small a hole easily choked with dirt in the gasolene?
36. What should be done when a jet chokes up?
37. Can a carbureter be made that will be less liable to choke up?
38. How is the speed of the gasolene engine regulated?
39. How does the float in a carbureter act?
40. What is meant by flooding the carbureter?
41. What must be done in such a case?
42. If the float were to leak, what would happen?
43. What is to be done if the float leaks while touring?
44. How can the float be repaired?
45. What is the specific gravity of gasolene?
46. How is gasolene obtained from the crude oil?
47. What is a hydrometer?
48. What practical use is a hydrometer to the motorist?
49. What materials are floats usually made of?
50. What is an auxiliary air valve?

STUDY HELPS.

Answers to Questions for Review.

No. III.—THE CARBURETER.

1. Gasolene is a volatile, colorless liquid distilled from crude petroleum, and is the fuel most commonly used in internal combustion engines for motor use.

2. The cylinder with piston, ignition chamber and valves, the connecting rod, and crank and the carbureter.

3. The carbureter is an apparatus used to transform liquid fuel, generally gasolene, into a gas and at the same time mix it with such a proportion of air as will make it combustible, so that it can be used in a gasolene engine in the same way as ordinary coal gas and air are used in a gas engine. Its name implies that it is the instrument whereby carburation is performed; that is, the saturation of air with a hydrocarbon, such as gasolene, in such proportion that an explosive gas is the result.

4. The function of a carbureter is to effect the carburation of air by saturating it with gasolene vapor, so that it forms an explosive mixture which can be fired to develop power.

5. Carbureters may be divided into two classes—surface carbureters and spray carbureters. In the surface carbureter air is drawn through or over the surface of the gasolene and carries with it a certain proportion of the liquid in the form of vapor. Sometimes a wick is used and the passage of the air through the wick, above the level of the liquid, carries with it a part of the gasolene which is drawn through the wick by capillary action. In the spray carbureter, gasolene is drawn by suction of the engine through a small orifice or jet so that it comes out in the form of a spray, the tiny atoms of which mix with the air current around the jet, rapidly vaporize, and form an explosive gas.

6. Spray carbureters are now almost universally used for motor car purposes. The atomizing of the gasolene in such carbureters has the effect of allowing it to combine more quickly with the surrounding air than in any other form. It must be understood that the actual vapor of the gasolene is not suitable for combustion in an engine. It must be mixed with a large proportion of air and experiment has shown that this proportion is somewhere about 13,000 cubic centimeters of air to one of gasolene.

7. The modern carbureter for automobile use most often consists of an inclosed apparatus, including a float chamber, with float to regulate the supply of gasolene from the tank; a spraying jet or nozzle, a spraying or carburating chamber, and the necessary valves for the admission of gasolene and air and for allowing the entrance of the explosive gas after carburation into the combustion chamber. The different spray carbureters, of which there are many forms, vary from each other mainly in the different means adopted for proportioning the gas and air supply to meet different conditions and different speeds of the engine.

8. The surface type of carbureter is economical in use, but is incapable of rapid alteration of the mixture, and on that account is now very rarely used for motor car purposes. There are three classes of surface carbureter, namely:

(a) The type in which air is drawn over the surface of a body of gasolene and, evaporating, carries off with it a certain proportion of the liquid.

(b) The type in which a capillary wick is utilized. This type is practically the only surface carbureter at present in use for motor car purposes. In the best known model, the body of air is drawn over the surface of a bundle of wicks, threaded out at their lower ends, and immersed in gasolene in a large inclosing tank. Warm air being drawn through the upper portion of the wick and coming in contact with the gasolene drawn up by capillary action, becomes charged with vapors and so forms the explosive gas.

(c) The type in which air is drawn through the liquid fuel.

9. The method of vaporizing the gasolene in a spray carbureter is purely mechanical. The gasolene is sprayed through a jet or nozzle, being drawn through it by suction from the engine, and the action of being forcibly ejected from a fine orifice breaks the body of the gasolene up into very fine particles or atoms, hence the term "atomizer" more nearly describes the action of the spray carbureter than any other word. Such carbureters are usually of what is known as the "float-feed" variety; that is, the supply of gasolene from the tank is regulated by means of a float contained in the supply chamber, called the float chamber. It is necessary in any carbureter to keep the level of the gasolene constant. For this reason, the gasolene cannot be fed directly to the jet or nozzle, but is fed to the float chamber adjacent to the jet, where it remains at a fixed height, except in case of accident or defect.

10. An automatic carbureter is one in which the nature of the explosive mixture is regulated automatically by the speed of the engine, thus securing greater flexibility in the engine. Most of the carbureters fixed to modern cars operate on the principle that in order to obtain maximum flexibility the mixture must be slightly richer in gas at low speed, while it may have increased air proportion as the speed develops. This object is now attained automatically through the engine speed.

11. The float is a cylindrical device originally of cork, but now more often of hollow spun brass or aluminum, which floats in the gasolene in the float chamber, and when the gasolene gets too low operates a rod and needle-valve which admits more gasolene to the chamber.

12. The jet, or spraying nozzle, is the device containing a small orifice through which the gasolene fuel is drawn and sprayed into atoms in the process of carburation.

13. The supply of gasolene from the tank is controlled by the float in the float chamber, which operates the needle-valve admitting more gasolene when the level becomes too low, and

thus maintains the constant level required, which is usually just below the level of the spraying nozzle.

14. The gasolene is drawn, by suction of the engine, through the spraying nozzle into the mixing chamber, which it reaches in the form of atomized spray. It then becomes mixed with the air flowing past the jet and the mixture is drawn through a valve into the cylinder head or combustion chamber, where it is duly compressed and then ignited to operate the piston by the expansion which follows.

15. The air is drawn into the carbureter by means of an inlet pipe, often around the hot exhaust pipe, or through a heated chamber. Provision is also generally made for more or less mixture with the air after the gasolene comes from the jet in the spraying chamber, this arrangement being necessary in order that correct proportions of gasolene to air may be maintained. It is usually effected by what is known as an auxiliary air valve.

16. The air supply is regulated by the speed of the engine; by the opening or closing of the throttle; by the operation of auxiliary air valves, etc.

17. "Mixture" is the name generally given to the explosive gas formed by the carburation of the air, by mixing it with gasolene vapor in its passage through the carbureter.

18. "Rich mixture" is the term applied to the explosive gas when it contains a larger proportion of gasolene than usual or larger than required. Too rich a mixture can be detected by the odor of unburned gasolene and by black smoke from the exhaust.

19. "Poor" or "lean" mixture is the explosive gas when it is poor in gasolene, as when the suction is not sufficient to draw enough gasolene through the spraying nozzle. Too lean mixture can be detected usually by a popping back into the carbureter.

20. The right kind of mixture is that with which the engine will perform uniformly good work under varying conditions and at different speeds, hence the quality of the mixture

must necessarily vary, as it does automatically according to the air supply, which in turn is regulated by the speed of the engine, which sucks it into the carbureter.

21. The mixture is fired, or exploded, by some sort of ignition system, generally an intermittent spark, after being compressed by the return stroke of the piston. Its expansion after ignition drives the piston outward and creates power. The results of the combustion are in turn driven from the combustion chamber or cylinder head through the exhaust valve by the return or exhaust stroke of the piston. The next or suction stroke of the piston draws in more mixture from the carbureter to be fired in its turn, and the operation is repeated indefinitely.

22. The combustion chamber is the cylinder head or chamber in which the explosive charge drawn from the carbureter is first compressed by the piston, then fired by the ignition system.

23. The force of suction from the engine draws the mixture from the carbureter into the cylinder head or combustion chamber through the inlet port. This force is created by the downward suction stroke of the piston in the cylinder, the inlet valve being opened simultaneously to admit the mixture.

24. The "mixture" is of the nature of an explosive gas which is readily fired and expands immediately upon ignition, as is the nature of such gases, thus creating the force which drives the piston in what is known as the working or power stroke of the four-cycle engine.

25. There are various methods of firing or igniting the explosive mixture. The principal methods employed in automobile practice are two kinds of electric spark ignition. In the earlier motor cars a hot-tube form of ignition was used in which a tube of platinum or porcelain, etc., was screwed into the wall of a cylinder and kept sufficiently hot to ignite fuel mixture by a separate outside gas burner. The spark now generally used for ignition can be obtained from (a) primary batteries; (b) secondary batteries or accumulators, popularly called storage batteries; (c) magnetos; (d) a small dynamo.

The spark is produced inside the walls of the cylinder head by means of a spark plug inserted therein, and of course connected to the source of electrical energy supplying the current, so arranged as to produce an intermittent spark to fire charges of fuel mixture in rapid succession.

26. In most internal combustion engines used in automobile practice, the carbureter is an important factor, being necessary to prepare the mixture by which the engine is operated. In some recent American cars, however, following European examples, gasolene fuel is directly injected into the cylinder head in proper "doses" to form the successive charges required for operation, each "dose" uniting with the proper quantity of air to form an effective mixture. In such cases the carbureter is eliminated, but in the great majority of automobile engines now in use, it is an essential factor of the engine.

27. Defects in the carbureter may cause difficulty in starting the engine; as, for instance, when the float level is too high, which will cause flooding of the carbureter, too rich a mixture and sluggish starting, if any. Or the float level may be too low, causing a weak mixture. Dirt in the carbureter, choking the spray nozzle, is a common cause of difficulty. In such a case, of course, the fuel supply being cut off, the engine will refuse to run. Or the valves may be stuck, interfering with suction and compression and thus causing difficulty. Or water in the gasolene tank, carbureter or supply line will occasion difficulty in starting. These possible troubles arising from derangement of the carbureter will readily suggest themselves, as the entire fuel supply must necessarily pass through the carbureter. It is very important that no water should get into the air intakes of a carbureter.

28. Every carbureter is adjusted so that the level of the gasolene in the float chamber is kept constant by the operation of a needle-valve controlled by the float. When the level falls ever so little below the proper point, the dropping of the float opens the needle-valve and admits more gasolene. When the proper level is reached, the rising of the float closes the

needle-valve and shuts off further supply until it is required, thus maintaining the level.

29. When too much gasolene passes through the jet in proportion to the air with which it is combined in the mixing chamber, the mixture becomes "too rich," and this will result in a loss of power in the engine. There are various ways of ascertaining when the mixture is "too rich," as by the smell and color of the exhaust.

30. The supply of fuel to the engine is controlled by means of a throttle, which is usually a disk fitted in the inlet pipe. It can be turned through an angle to close the inlet pipe, the disk being the same size as the interior of the pipe. The throttle is turned by a lever outside the pipe, the lever being worked by hand or by the governor. Some throttles take the form of a piston working in a short cylinder. The closing of the throttle diminishes the supply of mixture to the engine.

31. The supply of mixture can be increased by the gradual opening of the throttle until the engine is running with the throttle wide open.

32. An unsuitable mixture may result in a number of evils, including loss of power, misfiring, waste of gasolene, overheating, sooted spark plugs, smelly exhaust, popping behind the inlet valve, explosion in the muffler, failure to pick up until some moments after the new position of the throttle has been adopted; pre-ignition, with resultant damage to crankshaft or connecting rods; failure of the engine to stop when the spark has been interrupted, etc. Some of these evils are sometimes due to other causes, but may often be due to a badly adjusted carbureter.

33. The action by which gasolene is drawn through the spraying nozzle or jet by the suction of the engine may be illustrated by that of the wind passing over the waves of the sea and causing spray; for instance, the mist often noticed on the seashore in certain high winds.

34. The size of the orifice in a spraying nozzle varies in different cars according to the power of the engine. On small engines it is about the size of a large sewing-needle.

35. Although precautions are usually taken to filter the gasolene before it is placed in the tank and also to strain it before reaching the spraying nozzle, the nozzle is frequently choked up, as it requires only the smallest particle of dirt or metallic dust, etc., to choke it.

36. When the jet is blocked it is well to try flooding before taking the carbureter down. This is simply a matter of holding the float down, according to the way gasolene is admitted, so that the full head of gasolene in the tank may come through to the jet. In most cases this will free the nozzle from obstruction. Should the engine again show signs of flagging, it should be raised a little with the extra air inlet closed. This puts so strong a suction on the jet that it will often remove the obstruction without stopping the car. It may be necessary if the above methods do not prove effectual, to remove the jet should it be accessible and clear it out. The jet being cleared, it may be replaced and flooded in order to ascertain that all is perfectly in order.

37. Carbureters of the Longuemare type are less liable to choke than some others. In these carbureters the upright pipe is larger and closed with what may be termed a mushroom valve. This is screwed down tight so as to entirely close the opening, but to allow gasolene to pass. Fine slots are cut or filed in the valve, these varying in number from eight to twelve, so that it is almost impossible to get them all choked. The so-called mushroom valve is unscrewed by means of a square head on which a spanner can be placed. It can be removed, cleaned and replaced in a few seconds. The minor advantage of this type of carbureter is that if the engine gets more gasolene than is necessary, one or more of the slots can be closed with solder.

38. The speed of the engine can be regulated by means of the throttle or valve fitted in the inlet pipe and governing the admission of the mixture to the combustion chamber. The throttle is operated by hand or by the governor.

39. The gasolene enters the float chamber in a typical carbureter by a pipe at the center and bottom. This is closed by

a rod, the lower end of which acts as a valve, the upper part passing through the governor of the float chamber. The float being cylindrical or rather ring shaped, it floats round this rod. By means of small levers it lifts the rod when the gasolene gets too low and admits more. The methods vary in different carbureters, but the general principle of float-feed carbureters is the same.

40. The carbureter is flooded by raising the needle-valve so as to get an excess of gasolene, and this is sometimes required for starting the engine. When persistent flooding of carbureters occurs, it means too rich a mixture for good work, and is generally due to one of two things: Failure of the needle-valve to seat properly, or a punctured float.

41. In case of the needle-valve failing to seat properly, the difficulty can be overcome by "grinding in" the valve. A punctured float must be repaired without delay, or a new float fitted.

42. When a float leaks, the small quantity of gasolene which enters through the puncture upsets the balance and allows the gasolene level in the float chamber to rise higher than it should do, and consequently to flood.

43. The best thing to do if the float leaks while touring is to partially close the cock on the gasolene supply pipe and give the engine as much air as it will take. The float must be repaired as soon as possible.

44. A punctured float can be detected by shaking the float, when the liquid can be heard inside. The float should be thoroughly cleared of gasolene and the holes stopped up with very small quantities of solder. If the float is immersed in very hot water the gasolene will evaporate and bubble out of the puncture. A temporary repair can often be effected by drying out the gasolene and painting a little shellac over the leak.

45. Gasolene is the lightest volatile liquid produced, commonly obtained from the distillation of petroleum, its specific gravity being from .629 to .6673. The specific gravity of what

is sometimes called .680 gasolene varies with temperature, but is supposed to be measured at 60 degrees Fahr. It is .667 at 87 degrees Fahr. and .693 at the freezing point, 32 degrees Fahr.

46. The crude petroleum is placed in retorts and heated. The lighter portions are distilled off first, of which gasolene forms a small proportion. Then the heavier oils come off, such as kerosene, which is used for illuminating purposes. These comprise nearly half the bulk of the crude oil. Then come heavy lubricating oils and finally paraffin wax.

47. A hydrometer, literally a "water meter," is an instrument, often in the form of a glass tube weighted at its lower end, which when placed in a fluid floats higher or lower according to the weight or specific gravity of the fluid. It has a graduated scale and rests at the mark 1 when placed in fresh water. If placed in kerosene it sinks deeper, oil being lighter than water. If it is placed in gasolene it sinks more deeply still, showing the mark indicating its density on the graduated scale.

48. The hydrometer or, as it is sometimes called, the densimeter, is useful to motorists especially when touring, to test the specific gravity of the gasolene offered for sale at the various garages.

49. Carbureter floats are sometimes made of cork, but more often take the form of an air-tight cylinder or cylindrical ring made of spun brass, aluminum, etc.

50. The auxiliary air valve is a device fitted in connection with many carbureters to supply additional air for the mixture when the engine is running at the higher speeds. A lot of gasolene may be wasted when the carbureter does not supply sufficient air, and an extra air inlet is therefore a good thing. There are many ways of increasing the air supply. In modern practice an auxiliary air valve is often inserted in the inlet pipe and works automatically. In a representative carbureter the auxiliary valve is held to its seat by a spring, and the engine suction on medium and high speeds opens it to that

distance which the spring tension permits. This adjustment being properly made, the suction of the engine regulates the mixture automatically by pulling the valve open to the proper distance. Air must not be admitted through the auxiliary air valve on low speeds or starting will be almost impossible; so that the valve must be made to seat properly.

STUDY HELPS.

Questions for Review.

NO. IV.—ELECTRICITY.

1. How can electricity be defined?
2. Into what classes are substances divided as regards their electrical properties?
3. How many kinds of electricity are there?
4. What is a primary cell?
5. What is a storage cell?
6. What are the principles of a dynamo?
7. Name some of the uses of electricity in connection with motor cars.
8. What are the principal electrical instruments used in motor cars?
9. What are the principal units of measurement in electricity?
10. What is meant by voltage?
11. How is the ohm calculated?
12. What is meant by the amperage of an electric current?
13. What is the difference between high tension and low tension currents?
14. What is the principle of an electric motor?
15. What are the essential parts of an electric motor?
16. How is its speed regulated?
17. What is a commutator?
18. What is the rate of speed of an electric motor?
19. How is an electric motor reversed?
20. What is a controller?
21. How are the cells in the battery of an electric car arranged?
22. Describe the driving gear of an electric car.
23. What is electrolysis?
24. What is an electrode?
25. Describe the construction and operation of an electromagnet.

STUDY HELPS.

Answers to Questions for Review.

NO. IV.—ELECTRICITY.

1. Electricity is one of the many forms of energy, the cause of an important class of phenomena of attraction and repulsion, chemical decomposition, etc. The term is also often applied to the phenomena themselves. Heat, light, etc., are other forms of energy, each, like electricity, governed by its own laws and having distinctive phenomena.

2. All bodies will conduct electricity, but scientific experiments show that all substances fall into two great classes as regards their electrical properties, namely, conductors and non-conductors or insulators. The conductors of electricity require to be insulated from the ground and from their surroundings by the other class of bodies called insulators, to prevent the electricity escaping. The first-class insulators offer so great a resistance to the passage of electricity that a current at an enormous tension is required to traverse them. Hence, for all practical purposes, they are really non-conductors with all ordinary currents.

3. At first it was believed that there were two kinds of electricity, which were called positive and negative, but it is now known that all electricity is the same in kind, but different in degree. The old terms "positive" and "negative" are still retained, but as now used imply merely that one body—the "positive"—is electrified to a higher degree than another.

4. The primary cell or voltaic cell, discovered by Volta, is the means by which a current of electricity is produced by chemical action as distinguished from electricity produced by friction. Volta discovered that when certain substances were placed together in certain positions, changes occurred in their chemical composition, these changes producing a flow of electricity from the substance most acted on to that which was least acted on.

5. Storage batteries as understood by motorists generally consist of a combination of storage cells, scientifically known as secondary cells or accumulators. The action in these is also chemical, but with this difference from primary cells, that by passing a current of electricity through them from some outside source it is possible to exactly reverse the chemical changes that have taken place during discharge, so reproducing the original conditions. With storage cells it is therefore possible to store up energy derived from primary cells and then, by connecting the cells up in different ways, to obtain a current for use as required.

6. In a dynamo the phenomena of magnetism are combined with those of electricity in a single machine. The lines of force between the two poles of a magnet are continuously cut by coils of insulated wire, thereby inducing a current of electricity to flow in the wire, which can be collected and utilized for outside purposes.

7. Electricity is used in connection with motor cars for many important purposes. In electric cars it furnishes the motive power. In gasolene cars it is the basis of the ignition system by which the explosive mixture in the cylinder is ignited to produce power. It also furnishes lights, etc.

8. The electrical apparatus employed on motor cars includes primary and storage batteries, induction coils, dynamos, magnetos, and motors, with various other appliances used for minor purposes.

9. The three units of measurement in electricity are the volt or unit of voltage; the ampere or unit of amperage, and the ohm or unit of resistance.

10. The voltage expresses the force or pressure of an electric current in volts, just as the pressure of steam is expressed in pounds per square inch.

11. The ohm, or unit of resistance which a conductor offers to the flow of current, is calculated by the resistance of a certain length and thickness of a column of mercury, having a known cross-sectional area and a known length at a fixed temperature.

12. Amperage is the quantity of strength of an electric current, measured in amperes, the unit being the quantity of current which is induced to flow from one body to another by a difference of potential of one volt between them, through a resistance of one ohm.

13. High tension and low tension are comparative terms applied to electric currents and merely mean that of two currents the one is at a very much higher voltage than the other. High tension current, used in jump-spark systems of ignition, implies a current of high intensity or pressure, as distinguished from its quantity; but the term is always relative.

14. An electric motor is similar to a dynamo, but instead of converting motion into electricity, it converts electricity into motion. In other words, it transforms one form of energy into another.

15. An electric motor consists essentially of electromagnets and an armature. The construction is practically the same as that of a dynamo, but by a different arrangement of the armature wiring a greater power to start from rest under a load can be obtained.

16. The speed of an electric motor is regulated by the supply of current.

17. The commutator in an electric motor is a cylinder formed of a series of insulated copper sectors arranged concentrically around the armature spindle at one end of the armature core. The wires of the armature are connected to the copper sectors forming the commutator, each wire forming a separate coil wound about the armature core. The object of a commutator is to commute or change the direction of the flow of current. The term commutator is also applied to the electrical device called a "distributer" or "timer," used in ignition systems.

18. Some electric motors run at a rate of 2,000 or 3,000 revolutions per minute, but those working at from 600 to 800 revolutions per minute stand sudden increase of current better.

19. An electric motor is reversed by introducing a reversing switch, by means of which also the motor can be used as a brake.

20. A controller is a device consisting mainly of a rotating cylinder, or adjustable resistance introduced into the circuit, whereby the different circuits are made for the variable speeds of an electric vehicle. It is provided with a handle or lever, the movement of which to the different positions effects the changes of speed, or rather power, as required. At starting, the current is switched on and the controller turned to the first speed position, when the car moves off at slow pace. The handle may then be moved to the higher speeds in turn.

21. Each cell in the battery of an electric car is usually coupled to its neighbor in series and the battery is arranged in four groups with say 10 cells in each group. The number of groups and cells, however, varies in different makes of electric car and variations of parallel and series coupling of the cells in the battery afford the means of regulating the power of the motor.

22. The actual driving gear of an electric car is very simple. If only one motor is employed, a pinion may be mounted on the armature shaft to gear with a large wheel on the balance-geared live axle. If two motors are used, the armature pinions may be made to gear with the large toothed wheels secured to the two driving roadwheels, no balance gear being necessary in this case. With two motors in use, the front wheels may be driven if desired, but the rear wheels are nearly always chosen as the drivers.

23. Electrolysis is the process of chemical decomposition of various substances by the electric current, as in a primary cell, where the metal is gradually decomposed by the acid or alkaline fluid known as the electrolyte.

24. The path by which electricity passes from or into the conducting medium, such as a solution, is called an electrode. The term is applied especially to the ends, usually in the form of plates, of the conductor or wires leading to the source of

the current and terminating in the medium of conveying the current. The positive and negative electrodes are called respectively the anode and the cathode.

25. The usual form of an electromagnet embraces a core of magnetizable substance, such as soft iron or nickel, placed within a coil of wire through which an electric current is passing. This magnetizes the core by induction, but the magnetic state thus induced continues during the passage of the current only and disappears almost entirely with its cessation. Thus an electromagnet may be defined as a magnet which owes its magnetic properties to the inductive action of an electric current.

STUDY HELPS.

Questions for Review.

NO. V.—IGNITION.

1. What is understood by an ignition system?
2. Why is electricity generally preferred?
3. What other systems have been tried?
4. Describe the system known as "hot tube" ignition.
5. How is electric ignition effected?
6. How may electric ignition devices be classed?
7. How is a primary current obtained?
8. How is a secondary current obtained?
9. How and where is the spark produced?
10. What are the results of failure of ignition?
11. Describe the circuits in a high tension system of ignition.
12. What happens when the ignition is cut off?
13. What is a contact maker? A contact breaker?
14. What is a trembler?
15. What is understood by a "wipe" system of ignition?
16. What is a trembler coil?
17. How can the primary and secondary circuit lines of travel in a car be traced?
18. How is ignition secured for an engine having several cylinders?
19. Describe the electrical connections of an ignition system using one trembler coil to several cylinders.
20. What is meant by a high tension distributer?
21. How is a dynamo used in ignition?
22. What are the methods of installing dynamo systems?
23. What is a magneto?
24. What is the chief reason for the introduction of the magneto system?
25. What are the disadvantages of storage batteries?

26. What are the principles underlying the magneto system of ignition?

27. What are the advantages of low tension magneto ignition?

28. What is the principal drawback of low tension magnetos?

29. How is a low tension magneto geared to the engine?

30. Why is a trembler coil necessary with a wipe contact?

31. What are the essential parts of a magneto?

32. How is the current in a magneto generated?

33. What are the features of the arc light armature?

34. What is a dual system of ignition?

35. What is a spark gap?

36. How are the wires in an electric ignition system grounded?

37. Describe a spark plug.

38. What is an intensifier?

39. In a battery system of ignition, what is meant by coupling "in parallel" and "in series"?

40. What is the principle of the induction coil?

41. What is understood by preignition?

42. Name some of the chief causes of preignition.

43. Name some of the causes of failure of ignition by batteries.

44. What is meant by ignition timing?

45. What is "advancing" the ignition?

46. What is meant by synchronizing ignition points?

47. What is a short circuit?

48. How is a short circuit in a coil generally caused?

49. Where are short circuits likely to occur in battery and coil ignition?

50. Name the principal causes of ignition failure.

STUDY HELPS.

Answers to Questions for Review.

NO. V.—IGNITION.

1. In gasolene cars an ignition system, consisting of some form of electric apparatus, is required to ignite the explosive mixture in the cylinder at the proper time.

2. Electricity is almost invariably used for the purpose because no other agent has proved itself so generally convenient, reliable and safe as electricity.

3. Other systems tried at various times are: (1) Ignition by a very hot tube; (2) ignition by a very hot wire, heated by catalytic action; (3) ignition by the injection of a very hot jet of air or gas, heated by compression in a small pump.

4. In hot tube ignition the explosive gas in the cylinder is fired by a tube passing through the cylinder wall and heated by an external flame from a gasolene lamp, etc. It has been practically abandoned, chiefly on account of the danger of fire from the flame, the trouble with the lamp going out, and the impossibility of advancing or retarding the moment of firing while the car was in motion.

5. Electric ignition is always effected by passing a small electric current (rendered visible by its effect as a brilliant spark) through the mixture of gases it is desired to fire.

6. Electric ignition devices may be classed in two groups —high tension and low tension devices—and excellent results are obtained with either system.

7. The primary current of an electric ignition system is obtained from storage batteries, dry batteries, a dynamo driven by the engine, or a magneto machine driven by the engine.

8. The mere steady flow of a primary current has no useful effect in securing ignition. A secondary current of greater

intensity is required in a high tension system to fire the gases and this is induced in various ways and is kept quite distinct from the primary, flowing in a separate circuit. It may be induced in an induction coil through the sudden interruption of the primary current by some mechanical device, or in a magneto machine, dynamo, etc. Its quantity or amperage is low, but its pressure or voltage is very high. The production of a secondary current, either by a magneto or in the secondary winding of an induction coil, depends on the fundamental phenomenon that a current is "induced" in a wire or coil of wire which is exposed to the influence of a magnetic field of varying strength.

9. A secondary or high tension current has a tendency to cause a spark at the weakest point in its circuit, hence a weak spot in its insulation is purposely provided at the place where the spark is wanted, namely, inside the cylinder at the place where the points of the spark plug, so called, are nearest to one another.

10. The tendency of the high tension current to break down insulation makes it necessary to guard against weak spots occurring anywhere else than at the proper place in the cylinder. Otherwise the ignition will fail and misfires or total stoppage of the engine will result.

11. In all high tension systems, using a battery, there are two circuits—the battery or primary circuit and the spark plug circuit, which conducts the secondary or high tension current. These circuits must be completely closed or the current will not flow.

12. If the continuity of any closed circuit is interrupted, the current in that circuit stops, no matter at what point the interruption may be made. Hence turning the control switch stops the entire ignition system and therefore stops the car.

13. A contact maker is a device used with a battery and coil to cause the ignition spark to appear in the space between the points of a spark plug by intermittent closing of the circuit of the high tension current. A contact breaker, also called a commutator or timer, is a revolving device used to secure

the firing of the mixture in the cylinder at the proper time. The terms contact maker and contact breaker are often used as interchangeable in motor car practice. They always refer, however, to the device in any system by which the ignition circuit is completed or closed intermittently. "Make-and-break" is a synonym frequently used.

14. A trembler is a device used to cause a large number of additional "makes and breaks" of the circuit with more suddenness than is possible with a rotary contact maker. Many systems dispense with it, but use other means of effecting the same object.

15. A "wipe" system is one in which the circuit is closed by a metallic brush wiping or brushing against another metallic part. There are several kinds of wipe contact breakers, nearly all differing from the ordinary make-and-break in that the rotating part has neither notches nor projections.

16. A trembler coil is an induction coil having a trembler mounted upon it. Several trembler coils may be used in connection with one battery, or there may be only a single trembler coil to fire a multicylinder engine, etc. A trembler coil is distinguished from the non-trembler coil used where a trembler contact maker is adopted.

17. The electrical wires or conductors in a motor car are necessarily invisible for a part of their length, when they enter each piece of apparatus, but the lines of travel of both the primary and secondary circuits can be traced by means of the wiring diagrams usually supplied by the makers.

18. For several cylinders the whole ignition system for a single cylinder could be duplicated to ignite the charge in each cylinder in turn, but it is simpler and cheaper to use either one battery for all the circuits and as many trembler coils as there are cylinders, or, simpler still, one battery and one trembler coil for all the cylinders.

19. In this case the electrical connections of the primary circuit are substantially the same as when one coil is used to make a spark in one cylinder, but instead of there being only

one closing of the circuit by the brass brush pressing on a brass segment once for each revolution of the contact maker, a number of segments are introduced, one for each cylinder.

20. The high tension distributer is a device for conveying the high tension current to various points in rotation, making contact with as many contact pieces as there are plugs to be fired. Its function is to synchronize the firing of the different cylinders and to obviate the necessity of having a separate coil for each cylinder of a multicylinder engine.

21. When facilities for recharging batteries are not available, they may be dispensed with by employing some of the power of the engine to generate on board the car the electricity required when it is wanted. This is done by means of a dynamo driven from the engine by spur, chain, belt, or friction gearing.

22. The dynamo system may be installed by connecting the dynamo terminals direct to the ends of the primary windings of the induction coil, or by connecting the dynamo terminals to a storage battery, so that the current from the dynamo is used merely for recharging the battery. The second method has the advantage that the battery is kept continually charged, and it also provides a spare source of electricity in case of failure of the battery; while should the dynamo fail, the battery is ready charged.

23. A magneto is a mechanical appliance used to transform magnetic energy into electric energy. Its full title is "magneto electric machine" and various forms of the device are used in motor car ignition.

24. The chief reason for the introduction of the magneto system is found in the disadvantages of storage batteries, most of which are obviated by the use of the magneto.

25. These disadvantages include their weight, volume, brittleness of case, overflow of acid, liability to become exhausted without giving warning, low internal resistance, difficulty of knowing whether battery is charged or not, delay of recharging, etc.

26. Roughly speaking, the magneto takes the place of the battery in an ignition system, but as the current obtained is an alternating current, the rest of the ignition apparatus is modified to suit the different conditions. All magneto systems use the magneto proper to generate low tension current, and an induction coil to convert it into high tension. The production of current, both by a magneto and in the secondary winding of an induction coil, depends on the phenomenon that the current is induced in a wire, or coil of wire, which is exposed to the influence of a magnetic field of varying strength. In magnetos, the magnetic field is provided by steel "permanent" magnets, between the poles of which a coil of wire is placed, and the variation is obtained by rotating the armature.

27. The advantages of low tension magneto ignition are the great amount of heat which can be provided at the spark and the simplicity of the electrical circuit.

28. The principal drawback is the introduction of moving parts in the cylinder, which gives it an appearance of complication.

29. A typical low tension magneto is geared to the engine so that a soft iron shield oscillates between the fixed armature and the magnet pole pieces. The oscillation of the shield varies the magnetic flux through the armature winding and so induces an electric current in it.

30. A trembler coil is necessary with a wipe contact to break up the primary circuit of the coil rapidly, and thus intensify the power of the induced current. The quicker the make and break at the trembler the more effective is the spark at the plug.

31. The magneto is practically a dynamo, consisting essentially of a number of steel magnets of horseshoe shape, arranged so as to form a tunnel or long arch, and an armature wound with insulated copper wire and disposed along the arch so as to lie between the ends or poles of the several magnets. The magnets are called permanent because, having been excited in the first place by a powerful dynamo, they retain their

magnetism for a very long time compared with ordinary electromagnets.

32. The current is generated in a magneto by the rapid revolution of the armature close to the poles of the magnet. The armature consists of a soft iron core surrounded by a coil of wire, and it is in the wire that the current is induced. By suitable devices, the current generated can be drawn off and used when it is at its highest intensity, in order to create a firing spark.

33. The arc light armature used in some forms of magneto ignition is remarkable because it is stationary, and also for the method of winding. There are two coils of wire, as in an induction coil, but instead of the two being kept strictly separate, one end of the fine wire is connected to one end of the thicker wire. The other end of the primary wire is grounded to the core, while the other end of the secondary wire is passed down the hollow spindle of the armature and connected to a device which leads the high tension current to the distributer. Although the two coils are directly connected, they have the desired effect and a current of great intensity is produced in the secondary winding.

34. Many whose cars are equipped with a magneto system of ignition prefer to use a battery and coil system as well, because it is often easier to start up a car with battery and coil ignition than with a magneto. With the former system it is frequently possible to restart the car simply by switching on. In order to reduce the complication, the two systems are often combined to a certain extent, and are then referred to as dual ignition. One set of plugs and one distributer can be used in common for both systems, and a switch is introduced to couple up the battery and coil, while it cuts out the magnet, and vice versa.

35. The spark gap is the gap at the plug which is jumped by the high tension current and where the spark occurs. An emergency spark gap or exit for the high tension current is sometimes arranged, to prevent the current from breaking

down the insulation and spoiling the apparatus, should it fail to jump the gap at the plug.

36. The wires in ignition systems are usually grounded by connecting them with various parts of the mechanism or of the chassis frame so as to form a complete circuit and answer the same purpose as connecting to ground or earth in a telegraph system.

37. The spark plug is usually composed of a metal body in the form of a rod or pin, insulated in a cylinder of porcelain or other non-conductor, and screwed into the wall of the cylinder head. The spark gap is provided between two points, usually made of platinum to stand the heat, one point being formed on the end of the insulated metal rod or pin, and the other on a short wire secured to the metal body of the plug. The pin is secured in the center of the insulation and projects from it at each end. The outer end is fixed to a terminal for connecting up the high tension wire. The spark gap, where the spark occurs, is usually about 1/32 of an inch between the platinum points.

38. An external spark gap or "intensifier" is frequently provided at the sparking plug terminal and consists of two metal points mounted on insulating material a short distance apart. The effect is that the current is momentarily obstructed by the outer gap, but in jumping across it gathers impetus which enables it to jump the inner gap also and so to produce the spark in the cylinder. As a spark also occurs in the outer gap, the device is useful as a visible indication of the state of the ignition.

39. A battery is said to be coupled "in parallel" when the positive terminals are coupled together and the negative terminals are coupled together. By this arrangement, the current may flow through any or all of them. When coupling "in series," the positive terminal of one cell is connected to the negative terminal of the next and so on throughout the battery. The current then flows right through all the cells in serial form before a circuit can be formed.

40. The induction coil acts on the principle that if two wires, or other conductors, are arranged parallel to one another and an electric current is passed through one of them, a current also passes through the other one at the same time. The wire through which the current is passed positively is called the primary, and the wire in which the current is induced is called the secondary. It has also been found that if the primary and secondary wires are different in diameter and length and in number of turns, the induced current will differ in volume and pressure from the primary current. Coils are therefore used in motor ignition to secure a current of great pressure or intensity and small volume from a primary current of low pressure and greater volume, as given off by the battery. For this purpose the primary wire in the coil is made thick and short, while the secondary is thin and long. The induction effect is considerably increased if a bar of soft iron—or better still, a bundle of soft iron wires—can be introduced as a core inside the winding of the primary and secondary wires. The latter must be kept insulated from each other.

41. Preignition is the shortened term for premature ignition, or too early firing of the charge in the cylinder, which may reverse the stroke of the piston.

42. The chief cause of preignition is failure of water circulation and overheating of the engine. If this should be suspected, it can be detected by placing the hand on the radiator and water jacket. If the former is almost cold, while the cylinder jacket is exceedingly hot, it will be understood that the pump is not working, or that there is an air lock in the radiator piping, etc. A short circuit in the contact breaker wire is a frequent cause of intermittent preignition, and there are various other causes which readily suggest themselves to the experienced motorist.

43. In battery ignition systems, partial or entire failure may result from troubles with the sources of current, the induction coil, the wiring, or the armature. All parts should be kept clean and be frequently inspected to make sure that the adjustments are correct.

44. The regulation of the time at which the spark occurs in each cylinder head is usually called ignition timing. This is effected by adjustments which every motorist will do well to study, so that he can if necessary make readjustments for himself in case of need.

45. Advancing the spark or advancing the ignition is the operation of advancing the time when the spark occurs in the cylinder head. The ignition is generally retarded when starting the engine and advanced when well under way.

46. The act of regulating the times of ignition in the various cylinders of a multicylinder engine so as to secure the best results is called "synchronizing ignition points."

47. Short circuits are caused by the tendency of the electric current to travel by the path which affords the least resistance. The resistance in the spark chamber between the points of the spark plug is very considerable, and consequently the current always tries to take a path of less resistance, sometimes breaking through weak insulation, etc.

48. A "short" in the coil is generally indicated by a ticking or buzz inside the coil, or by an excessive discharge of current, causing rapid pitting of the contact points. It may be due to a weak spot in the insulation.

49. Short circuits are likely to occur in the following units of an ignition system using a coil and battery: The wires and connections, the switch, the contact maker or breaker, the distributer, the spark plug, the coil or the battery.

50. The principal causes of ignition failure are short circuits, battery run down, spasmodic working of circuit, preignition due to overheating, timing wrong, loss of compression at rocking lever of igniter, disconnection of condenser, etc.

STUDY HELPS.

Questions for Review.

NO. VI.—COOLING SYSTEMS.

1. Why is a cooling system necessary with an internal combustion engine?
2. How are motor engines cooled?
3. What are the principal methods of air cooling?
4. Describe the Franklin air cooling system.
5. Is a fan necessary in an air cooled system?
6. What are the advantages of air cooling?
7. What are its disadvantages, if any?
8. What is usually meant by circulation in a motor car?
9. What are the essential features of a water cooling system?
10. What is the purpose of the radiator?
11. Why is a fan used?
12. What is meant by "natural" circulation?
13. What is meant by forced circulation?
14. What is a honeycomb radiator?
15. What are the advantages of such a radiator?
16. What is an air-lock?
17. How can an air-lock be cured?
18. How can the water circulating system be cleaned out?
19. What does steaming at the radiator indicate?
20. What is the purpose of a pressure gauge?

STUDY HELPS.

Answers to Questions for Review.

NO. VI.—COOLING SYSTEMS.

1. The great heat set up by the repeated firing of the explosive gases in an internal combustion engine renders it necessary to provide some sort of cooling system to prevent overheating, which would result in stoppage of the engine.

2. There are two systems of cooling motor engines in vogue—air cooling and water cooling.

3. Air, being a bad conductor of heat, is found useful for cooling hot parts of machinery by its action of convection. For example: A number of ribs or flanges, etc., are cast or otherwise formed around the cylinders of a motor engine so as to give the greatest superficial area, and the motor is so placed on the vehicle as to be subjected to the current of air met or formed by the running of the car. When the car is stationary, cooling still goes on to some extent, through the air in immediate contact with the cylinder ribs becoming heated and rising upward, a fresh body of cooler air replacing it, and a constant current being thus obtained.

4. In the Franklin system of air cooling the cast-iron cylinders have a series of thin heat-radiating flanges of phosphor bronze placed about them, and by these heat is transmitted directly to the air, a blast of which is driven about them by a fan. Other special features of the Franklin system include an auxiliary exhaust at the base of the cylinder through which more than 70 per cent of the gases pass off. The auxiliary exhaust opens just after the piston completes the power stroke.

5. In some cases a fan driven off the crankshaft is used to increase the current of air for cooling, though a fan is not essential and in small motors it is dispensed with.

6. The advantages of air-cooling systems are light weight,

absence of complication, rapid combustion and high fuel economy.

7. A disadvantage of air cooling as compared with water cooling is that the horsepower developed is less than that of water-cooled engines of the same dimensions, because the compression is made lower purposely to avoid preignition under ordinary circumstances, and because the weight of the charge taken in at every stroke is less for equal volumes. The great majority of cars nowadays are water cooled—this system being regarded as most uniformly efficient for motor car work in spite of the obvious advantages of an air-cooled system, other things being equal.

8. Circulation is the term often applied to the water-cooling system in connection with motors.

9. The essential features of a circulation system are the tank and radiator, water jackets and connecting pipes. In a typical modern system of circulation the tank and radiator are combined, the water flowing from the bottom of the radiator to the bottom of the water jacket and from the top of the water jacket to the top of the radiator. In such a system the pump, when one is used, is placed between the bottom of the radiator and the bottom of the water jacket. When the tank and the radiator are independent of each other, the water flows as follows: (1) From tank to bottom of water jacket; (2) from top of water jacket to radiator; (3) from bottom of radiator to tank. The pump, when used, is placed between the bottom of the water jacket and the tank.

10. A radiator is employed for the purpose of cooling the water heated by the cylinders so that it may be returned to the water jacket in a cooler state.

11. A fan is generally fitted to increase the air draft and assist in the cooling. The speed of circulation is also increased in a system of gravity-feed by the use of a rotary engine-driven fan behind the radiator.

12. In a system of "natural" circulation—also called the thermo-syphon system—no pump is used, but the tank is

placed above the water jacket and the cool water flows into the bottom of the tank. Gravity feed is simpler than pump feed, but not quite so efficient.

13. A system of forced circulation is one in which the water is forced through the system by means of a pump driven by the engine.

14. A honeycomb radiator consists of a tank containing water to be cooled, having threaded through it numerous honeycomb-shaped tubes through which the air can pass, the water lying in extremely thin layers between the adjacent sides of all these tubes. This type of radiator is placed directly in front of the car, so that the air can pass through it, the air current being increased by the forward motion of the car itself.

15. In the honeycomb radiator the cooling effect is so great that a very small quantity of water may be used, which lessens the weight required to be carried on the car.

16. Airlock is the term applied to the airbound condition arising in a water-cooling system when a bubble of air lodges in the top of some bend in a pipe and stops the water circulation or impedes it.

17. Airlock can generally be removed by running the engine so that the pump is in full operation; opening the water plug at the lowest part of the water system; opening the air relief cock which is usually provided at the top, and allowing a stream of fresh water to flow in through the filling up nozzle as fast as it flows out at the plug.

18. The water circulating system may be cleared of impurities after running with dirty water by filling up the tank with a strong solution of soda. After running the engine for a few minutes, the soda water must be drawn off and the system washed out with clean water. In making the soda solution, as much common house soda as the water will dissolve should be used. Rainwater is the best for water-cooling systems.

19. If any steam is given off at the radiator other than

the amount which experience of the car has shown to be usual, the driver may conclude that the water circulation is failing, and attention must be given to the matter at once. The pump is usually the cause of the trouble.

20. A pressure gauge, placed on the dashboard in view of the driver, is often used to indicate the condition of the circulating system.

STUDY HELPS.

Questions for Review.

NO. VII.—TRANSMISSION AND GEARING.

1. How does the engine transmit power to the road wheels?
2. What is meant by change speed gear?
3. What is the principle of such gearing?
4. How are the different speeds secured?
5. Why was it called the Panhard gear?
6. Describe this form of change speed gear.
7. Can the gear be changed when the engine is running?
8. Explain how this is done.
9. What is a clutch?
10. Do clutches require any care or attention?
11. Why does a clutch slip?
12. May not the clutch cause the car to start with a jolt?
13. Does the friction ever burn or injure the leather of leather-faced clutches?
14. Are there any other kinds of clutch?
15. What is the gear box?
16. How is the gear changed?
17. What is the operation of starting a car?
18. How does the driver change speed?
19. How does the driver change speed for hill climbing?
20. How is the reverse operated?
21. What is meant by direct drive?
22. What is the object of this arrangement?
23. What are the gear wheels made of, and how are they made?
24. How do these gears drive the road wheels?
25. What is meant by a bevel pinion and a bevel wheel?
26. What is a pinion?
27. Is there anything peculiar about this shaft.

28. Is there anything to keep the axle in its proper place?
29. What is meant by the chassis?
30. What is meant by a live axle?
31. But if a motor car has a live axle and wheels fixed on it, how can it get round corners?
32. What is the differential gear?
33. Is this arrangement used on all cars?
34. What are sprockets?
35. Are the chains of ordinary shape?
36. Do they not wear very quickly?
37. Do they stretch, and if so, is there a chance of their getting off the sprockets?
38. Which is the best arrangement, the live axle, or the fixed axle with two chains?
39. What are the advantages and disadvantages of the fixed axle?
40. Is it necessary to have two chains?.
41. Are there any other methods of driving the road wheels?
42. What is meant by pitch?
43. Name some other gears used on cars.
44. Are there any advantages in this gear?
45. What is meant by missing gear?
46. Is there nothing to prevent this happening?
47. Is it always effectual in stopping a car?
48. Is there no other means of preventing a car running back?
49. What is meant by a ratchet and pawl?
50. Describe the brakes for stopping a car.
51. Does this make a perfect brake?
52. Is the brake on the driving wheels like this?
53. Are there any other types of brakes?
54. Do the brakes require any care or attention?
55. Is it difficult to keep them free from grease and oil?
56. Is there anything that can be done on the road to assist a brake in holding?
57. Is there any other means of checking the car on a steep hill?

58. What effect has the friction of the brakes when descending long, steep hills? Does it not heat them?

59. Should a car be geared differently, according to the locality it is chiefly used in?

60. How is a motor car steered?

61. Why should not the whole axle swivel like that of an ordinary carriage?

62. What is meant by a fore-carriage?

63. Is there a fore-carriage in a motor car?

64. How does the steering wheel act on the road wheels?

65. Does the steering gear ever require any attention?

66. How are these pins tightened up?

67. What is meant by "reamered out"?

68. If the holes are much worn, would not the steering wheels be no longer parallel?

69. Is there any other way by which the wheels get out of parallel?

70. Do the driving wheels get out of parallel?

71. What can then be done?

72. What is the purpose of the levers on the steering wheel or below it?

73. Are throttles fitted to all cars?

74. Some cars make more noise than others; is there any method of stopping the barking noise from the exhaust?

75. Explain how the body of the car is carried.

76. Do the springs require attention?

77. What is the difference between a screw and a bolt?

78. How are nuts kept tight?

79. Is there any other way of keeping nuts from working loose?

80. Are there any other methods of keeping nuts tight?

81. What screws are used on French cars?

82. What is a kilometer?

83. How are spanners designated?

84. How are the cranks of two, four and six-cylinder engines arranged?

85. What is meant by the throw of the crank?

86. Why are all the wheels of a car made of equal size?

STUDY HELPS.

Answers to Questions for Review.

NO. VII.—TRANSMISSION AND GEARING.

1. The power is transmitted by means of gearing, by the change speed gear, and in some cars by chains.

2. As an internal combustion engine is not so flexible as a steam engine, the car must run at different speeds compared to the engine. A steam engine can work slowly, exerting great power, as the full pressure of steam can follow the piston up to nearly the end of its stroke. If one listens to a heavy train going up an incline, the beats of the exhaust are slow and very loud; when the train reaches the level the beats are more rapid and not so loud, as the engine is running faster. Now, the internal combustion engine has not the elasticity of a steam engine to run either slow or fast. It gives little power at slow speed, and therefore some gearing must be introduced to allow the engine to run at or near its normal speed while the car is going up a hill.

3. If the engine when on top speed, or third speed, as it is often called, makes five revolutions to one of the driving wheels, it might make ten on second speed and twenty on the first speed. Thus the engine would put four times the power on the driving wheels at slow speed that it did at fast speed.

4. By means of the change speed gear, originally known as the Panhard gear, or some modification of it.

5. Because it was introduced by MM. Panhard and Levassor, of Paris, who were early makers of motor cars; though a gear almost identical was designed by James Watt, the inventor of the condensing steam engine.

6. In a gear-box, which is a closed box made of aluminum, brass, etc., are two parallel shafts, one of which is turned by

the engine. On these are three pairs of toothed wheels; those on one shaft are firmly keyed in their places, those on the other shaft are on a pipe or sleeve, which turns with the shaft; but this sleeve carrying the wheels can be moved backward and forward on the shaft, so that any one of its wheels can be brought into gear with its fellow on the shaft driven by the engine. As these pairs of wheels are of different sizes, three different speeds can be got out of the car.

7. Yes; while the engine is running, but not when it is driving the car.

8. By means of a clutch which disconnects the engine from the gear. A pedal worked by the foot of the driver disengages the clutch.

9. Clutches are of various forms and types. A type commonly used on motor cars is a friction clutch. On the outside flywheel is a recess, which is bored taper or conical in the lathe, and the body of the clutch is also turned to the same taper, so that when the two come together they exactly fit and bite, and the flywheel then turns the clutch. The rim of the clutch is sometimes covered with leather to cause the clutch to bite or grip better, and it revolves with the flywheel just as if it were in one piece with it. The pedal worked by the driver's foot releases this clutch, and it soon comes to rest, as the weight of the inner part of the clutch is very light. Thus there is no strain put on the teeth of the wheels when the gear is being changed.

10. Yes; they will sometimes slip. If the slip is bad the engine may fail to move the car.

11. It slips from various causes. Water getting on the clutch or oil will cause slipping or the leather may be worn and glazed from the continual slipping that must occur each time the gear is changed. As the leather is dressed with oil, this may ooze out from the heat of the friction, or in very hot weather.

12. Yes. If the clutch is fierce it bites directly it gets home; in this case it must be let in very slowly.

13. Yes, if the clutch slips much; but it is very rarely such a thing occurs, and it is due to not keeping the clutch in proper order. If it slips on the road, a little fuller's earth should be put on the leather. The clutch should be held open, and the fuller's earth put on the leather with a thin knife-blade or a strip of paper. If it slips from oil or grease getting on it, it should, when the car gets home, be washed out with gasolene to remove the grease. A leather-faced clutch should be occasionally dressed with castor oil or special clutch dressing.

14. Yes; the metal-to-metal clutch, which is now very popular. It consists of a number of disks of thin steel, every other one being connected by studs, or some other means, to the flywheel, the other disks to the gear shaft. There is a little space between the disks. When they are compressed by the action of the foot releasing the spring they are forced together and bite. The disks usually run in an oil-bath.

15. The gear-box is the case in which the change speed wheels are placed; it is partially filled with grease, which is churned up by the gear wheels, keeping them lubricated, and as it is entirely closed, dust and dirt from the road cannot get in. In most cars there is a cover at the top, which can be taken off to inspect the gear.

16. By means of a handle or lever on the driver's right, which works alongside a bar, which is a segment of a circle. In this segment there are notches, into which falls a catch to hold the change-speed lever in gear; one of these notches is called the neutral. When the lever is in this notch the gear wheels are free, and the engine cannot move the car—the lever should be always left in this notch. Forward of this notch there are three others corresponding to the three forward speeds. Behind the neutral notch, in most cars, there is another, which is the reverse. In some cars a different lever is used for reversing.

17. The engine is started by turning the handle. The driver must see that the gear lever is in neutral, the sparking

retarded, and the air and gas adjustment right. If the car is not on level ground, the brake must be on. Having started the engine, the driver takes his seat, pushes down the clutch pedal, and sets the gear lever in first notch—slow speed gear. He then advances spark, gives the engine more gas, till it is running fairly fast, then slowly raises the pedal by his foot till the clutch bites, and the car moves on.

18. When he has run a short distance he again depresses the pedal and quickly shifts the gear lever to the second speed notch. Immediately it is in he raises his foot to let the clutch in, and the same is done with the third speed. No actual rule can be given as to retarding, sparking, or throttling gas in changing gear, as engines differ so much from one another.

19. As soon as the engine begins to labor, he brings the gear lever from third to second, of course throwing out the clutch. If the car will not then mount, he must bring it back to first. Care must be taken not to miss gear; that is, to fail to get the gear in. Then, the engine being disconnected from the car, there is a possibility of the car running back if brakes do not hold well. To know how to change gear can only be learned by practice on the car; but gear changing must never be attempted when the clutch is in. Neglect of this has often caused a breakdown, or, at least, injury to some part of the gear.

20. The sliding gear wheels are brought further back, beyond the neutral, till the slow speed gear wheel engages with a pinion which runs in the reverse direction.

21. Direct drive on top speed is frequently used on modern cars. The engine, by means of a dog clutch, drives the top speed without the intervention of the gear wheels on second motion shafts, these wheels then being idle, the arrangement being something like that on a lathe when the back gear is thrown out, and the lathe runs fast; when the back gear is in use, the object the lathe is turning runs more slowly.

22. There is less loss of power on top speed, and this speed is most frequently used. There are so many types of gears and speed changing that it would be impossible to mention all.

23. They are made of steel of high quality. The teeth are cut out with great accuracy by wheel-cutting machines. The teeth are afterward hardened, so that a file will not cut them. These wheels are usually so well made that they will run for several years. If engineers were not able to provide this high-class steel, the gears would wear out in a few weeks, even if they were able to run without breaking for that time.

24. From the tail of the second shaft—that is the one turned by the gear wheels—a long shaft runs back to the driving axle. On the after-end of this is a bevel pinion which gears into a larger bevel wheel on the live axle.

25. Toothed wheels, in which the teeth are on the edge of the wheel, so as to give a turning motion at right angles.

26. The smaller of two geared wheels.

27. Yes. It is what is termed a universal shaft. It has couplings at each end. Each coupling consists of two jaws, which embrace a block of metal, and pins go through the jaws of the coupling, which are at right angles to each other, and through the block of metal. These couplings allow the shaft to revolve at an angle with the shaft in the gear-box, and the couplings at the after-end allow it to work at an angle with the line of the shaft of the bevel pinion. This is necessary, as the springs of the car allow the road wheels to have an up-and-down motion relatively to the body of the car. These universal joints are sometimes called Hooke's joints, from their inventor. The shaft is sometimes called the cardan shaft, a French term.

28. Yes; the radius rod, extending from the bevel gear case on the axle to some part of the frame of the car. In live-axle cars it often consists of two rods braced together in the middle like a capital ≪. The legs of the radius rod are secured to the top and bottom of the bevel gear case, and keep

it in its place; if there were not this braced rod, the gear case would have a tendency to turn around about the axle, and not to turn the axle, when something would break.

29. "Chassis" is a French word, meaning the whole frame—engines, gear, and wheels—as completed ready for the coach-builder to fit on the seats, mudguards, etc. The coach-builder's work is generally termed the body.

30. An axle that revolves. A railway axle is a live axle; that on an ordinary road carriage is not—the wheels must turn independently in going round a corner. The curves on a railway are of such great radius that the wheels are able to slip a little on the rails and get around without any difficulty.

31. The axle is in halves, and coupled by the differential gear.

32. It usually consists of two equal-size bevel wheels, one on each inner end of the half axles. These gear with either two, three or four bevel pinions. The whole is contained in a case or frame, the axle going through its center, and the case is turned by a big bevel wheel surrounding one side of the case, which bevel wheel is driven by the universal shaft from the engine, or by a chain in central-driven chain cars. As these bevel pinions are in gear with the two bevel wheels, they cannot revolve on their axis, but simply act as drivers, and turn both bevel wheels round, and with them the axle. But if the car is steered to one side, they allow the outer wheel to travel faster than the inner wheel, and the bevel pinions move a little on their axis, so the car can easily get round a corner.

33. Some sort of differential must be used on all cars with two driving wheels; but in cars with fixed axles, in which each wheel is driven by a separate chain, there is a shaft across the chassis, and in this shaft is the differential. On the ends of this cross shaft are the sprockets, from which the chains run back to the driving axle.

34. Toothed wheels, to carry a chain.

35. No. They resemble bicycle chains, only they are very much stronger and heavier.

36. Yes, they do wear, but not so quickly as one would suppose. A pair of chains should run 4000 or 6000 miles.

37. They do not stretch, but they are tightened by lengthening the radius rods. With chain-driven cars there are two radius rods, one on each side, and these can be lengthened, as the chains wear or stretch, by turning a nut, which has right-hand and left-hand threads in it. Each radius rod is in two pieces. These are coupled by the nut which has the right and left threads in it, one at each end. The nut is of considerable length, 5 or 6 inches long.

38. That is a matter of opinion. The live axle is, perhaps, cheaper to make, and the car so fitted is easier to clean, but as the axle is always revolving it is exposed to greater strain than the fixed axle, and is more liable to break. The differential, being also exposed to a greater strain than in the chain-driven car, where it has only one-quarter or one-half the strain on it, is more likely to give trouble. The weight of the live axle being necessarily more than the fixed axle, and resting directly on the wheels, is more likely to punish the tires than the lighter fixed axle. But in modern practice the live axle is generally preferred on all but the heaviest cars.

39. There is a certain flexibility in the chain which probably relieves the engine and gear of some little strain in starting and changing speed. If a chain breaks it is comparatively easily mended; the great advantage is the facility it allows of altering or lowering the gear of the car at a little expense, by putting smaller sprockets on the driving shaft. This alteration may be found very useful in hilly districts in winter, when the roads are soft or covered with snow. A chain-driven car (unless the chains are well cased in, which is not always done) takes longer to clean than a live-axle car, as the chain must be kept clean and lubricated with grease and graphite, etc.

40. No; there are many cars which have only one, a central chain driving on to the differential case of the live axle.

41. Yes, several. Belt-driving was used in conjunction with chains in the old Benz cars; if the belts were of good quality, and well looked after, they worked well. Then, some cars are driven by worm-gearing. A worm is a screw of coarse pitch which is geared into a wheel to correspond.

42. The pitch of a screw is the distance apart of the threads or turns. The thread used by gasfitters on gas-pipes is a fine thread; that on the screw of a vise is a coarse thread.

43. The epicyclic gear as used on some well-known makes. This consists of a train of wheels one within the other. When the engine is running on top gear, these are locked by a brake and all revolve together. When running on low speed one wheel is braked and is stationary, the other wheels revolve, letting the engine run faster, and an intermediate wheel drives the car by means of a chain.

44. Yes; it is almost impossible to miss gear.

45. Not getting the gear in when changing speed. If this happens on a steep hill the car may run back.

46. Yes, the brakes; but sometimes they may fail to hold the car. Some cars are fitted with a sprag which can be dropped to trail on the ground, and as its end is pointed it catches in the road when the car runs back, and stops the car. The sprag is lifted from the road by a cord, and only used on steep hills.

47. No. On a very hard road or asphalt it sometimes fails to bite. On a very soft road it may go in too deeply, and if the car runs back it may jump the sprag.

48. A ratchet wheel is fixed on the gear-brake drums, and a pawl drops into this.

49. A ratchet wheel is a wheel with teeth on its rim; these teeth are not like those in ordinary gear wheels, but are inclined. The pawl is a pointed catch pivoted near the wheel, and drops into the teeth, only permitting them to revolve in one direction. In the winding of clocks a ratchet and pawl are used.

50. There are usually two brakes fitted. One is generally worked by the foot, is connected to the gear shaft, and as it revolves at a higher speed than the road wheels it has more braking power than if it revolved more slowly. It usually consists of a pulley with a flat rim and flanges to prevent the band working off; the band is tightened by the treadle acting through levers, and it exerts considerable pressure on the pulley. The steel brake band is lined with either leather, cotton belting, copper, etc.

51. No. A good deal of its action depends on the gripping of the band itself on the pulley, which tightens the tail of the band, so that sometimes it will not hold the car from running back.

52. Some cars are so fitted, but it is best to have the brakes fitted with short levers. This brake will hold a car from running back.

53. Yes; the internal expanding brake. This works on the inside of a drum on the driving wheel, and levers expand a ring fitting loosely in the drum. It has good holding power.

54. Yes; the driving wheel brakes must be carefully adjusted, so that they press equally on both drums, otherwise the car may swerve to one side when the brakes are applied if one has more holding power than the other. They must be kept free from grease and oil.

55. It depends on the position and arrangement of the brake. If the gear-box lets the grease escape, it often finds its way on to the brake. It is best washed off with hot water, in which some soda has been dissolved. It may be advisable to apply a little fuller's earth. If on a trip the brakes are found not to hold properly, they should be attended to before the car goes out again.

56. Dust, scraped up from the road and sprinkled on the brake pulleys, will often help a brake to grip.

57. Yes; by using the engine as a brake. If the gas is entirely shut off, or the electric current switched off so that the engine cannot fire, the engine acts as a brake. In this

case the car drives the engine round, and this checks the car. An engine requires some considerable power to turn it round, as every one knows who has experienced difficulty in starting an engine. If the car is put in second speed it will have a greater braking effect than in top speed, as the engine is turned so much faster. On coming to the top of an unknown steep hill some drivers stop the car and put in the lowest speed and go down on that.

58. Yes; some large heavy cars are fitted with a tank containing water under pressure, with an arrangement to let this water trickle on the brakes when going down long, steep hills. It must be remembered that brakes that would hold a car on ordinary hills might be quite unable to do so on the long and steep grades of a hilly country.

59. Yes; a car for a very hilly country, or for work on bad roads should not be geared so high as a car that is used in the neighborhood of cities where roads are good and there are no very steep hills.

60. By means of the front wheels, which are pivoted on the end of the front axle.

61. Because the effort of turning the whole fore-carriage would be too great. If one wheel struck an obstacle, such as a stone, that wheel would be violently checked, and the car would swerve to one side. This arrangement is only used on traction engines and very slow-moving vehicles.

62. It is the term given to the front axle, springs, etc., of an ordinary road carriage. It is the whole part that swivels in going round a curve.

63. There is no fore-carriage, as the word is generally understood, in a motor car.

64. At the lower end of the steering pillar, under the foot-board, there is a worm, which acts on a segment of a worm-wheel. A lever from this leads to a lever on the vertical spindle on which one of the front wheels swivels; a rod from this goes across the car to move the other wheel. In some

cars the steering shaft has a coarse thread cut on it, and a nut fits on this, and the nut, by links or rods, moves the steering wheels right or left.

65. Yes; the pins which join the levers and rods get worn and permit the wheels to wobble about. This makes steering difficult and wears the tires.

66. In some cars there is an arrangement for tightening for wear; but in most cars new pins must be fitted, and the holes reamered out to fit the new pins, for the holes will have worn oval.

67. A reamer is a steel tool for making a hole a little larger than it is. It is a steel tool the size of the hole, with a cutting edge all up it. The nose of the reamer is tapered, and lets it go in the hole, and it is then turned round by a wrench.

68. Yes; and wheels that are not parallel wear out their tires very quickly. They also make the car run heavily. But there is an adjustment in the cross-rod which couples the wheels, for bringing the wheels parallel.

69. Yes; by a collision, or by some part being strained on a rough road, or by getting out of a hole or ditch.

70. Sometimes this occurs with fixed axle cars after a collision or the car has been strained.

71. The axle must be taken out and straightened by a blacksmith.

72. These vary in different cars. One is for advancing or retarding the spark; another for adjusting air and gas; a third is the throttle, that is if the throttle is not worked by the foot.

73. Not throttles as described above; but there must be some way of varying the speed of the engine. In some cars this is done by altering the lift of the exhaust valve so that more or less of the burned gases are left in the cylinder, and thus little explosive mixture can get in.

74. Yes; the muffler. This is a cylindrical box of sheet

metal into which the exhaust gases are led by a pipe from the engine; here they expand before passing into the atmosphere. There are various forms, some with plates in them so that the gas expands less suddenly; some are simple drums with small holes for the gases to escape.

75. On springs; the middle of each spring is bolted by clips to the axle; the ends are carried by links attached to what are termed dumb irons, bolted to or forming part of the frame of the car.

76. The bolts which clip the springs to the axle must be examined from time to time to see that they do not work loose; also, as the leaves of the springs bear on one another, they work with the up-and-down motion of the axle—as may be noticed by the paint being rubbed away at the end of each leaf of the spring and grease or oil should be rubbed into these places. The eyes and hooks of springs should be oiled.

77. A screw is screwed into its hole, like the wood-screws used by carpenters; a bolt is a screw with a head at one end, and is tightened up by its nut.

78. Frequently by lock-nuts; that is, two nuts. The first one is screwed down hard, the lock-nut is then screwed on it, and they are tightened by using two spanners. One holds the first nut from moving, and the other screws the lock-nut tight up against it.

79. Yes. A split pin is put through a hole drilled in the bolt just above the nut; the tails of the split pin are then opened out.

80. Spring washers are sometimes put under the nut. They are washers cut across at one side; the edge of the cut digs into the nut and prevents it turning. They have also a certain amount of spring in them, which takes the jar or shake off the nut. Nuts that have worked loose continually are often secured by using a spring washer; there are several different types of spring washer.

81. Screws with meter pitch. The French measure of length is the meter, 39.37 inches; it is divided into decimeters, centimeters, and millimeters—respectively the tenth, the hundredth, and the thousandth of a meter.

82. About five-eighths of a mile, or exactly 0.6214 of a mile, or 1,093 yards.

83. Spanners are of two kinds: adjustable, so that the spanner will grip nuts of different sizes; and solid spanners. The latter are known, not by the size of the jaw, but by the size of the bolt the nut of which they fit.

84. On two-cylinder engines the cylinders are sometimes opposite one another, like bicycle cranks, but frequently side by side, which gives a more regular turning effort than if the cranks were opposite, the two working strokes being at equal distances apart in the revolution. In four-cylinder engines two cranks are up and two down. In six-cylinder engines they are arranged 120° apart, the cranks being together.

85. The radius of the crank pin from the center of the shaft. If the engine has a stroke of, say 6 inches, the crank throw is 3 inches.

86. So that the tires are interchangeable. The driving tires wear out more quickly than the front ones, so that when a driving tire is somewhat worn it can be run on a front wheel, and a new tire placed on the driving wheels.

STUDY HELPS.

Questions for Review.

NO. VIII.—TIRES.

1. Explain the action of a pneumatic tire.
2. What does a pneumatic tire consist of?
3. How is the tire kept on the rim?
4. What is meant by "bead of the tire"?
5. Does a knowledge of bicycle tires help one in looking after motor tires?
6. How is a tire put on?
7. What is a jack, and how is the wheel jacked up?
8. What is meant by security bolts or tire bolts?
9. What is next done?
10. Is there any risk of injuring the inner tube in doing this?
11. Why is chalk used?
12. What air pressure should be put in the tire?
13. How is this pressure ascertained?
14. How can this be told?
15. Is not this high pressure likely to burst a tire?
16. How is a tire taken off?
17. How is a puncture mended?
18. Why is this done?
19. What are the patches like?
20. What is done to the patch?
21. What is meant by "tacky"?
22. How long does the patch take to set?
23. Can this be done when traveling?
24. If a patch is not at hand, can anything be used in its place?
25. Is there no other way of mending tubes?
26. How is this done?

27. How are the inner tubes carried in the car?

28. Would not larger wheels be better than the small wheels now used on cars? Traction engines have wheels six feet, or even more.

29. If an outer cover or casing bursts on the road, what can be done?

30. If a casing shows signs of wear, what can be done?

31. Is this the only way to mend a casing?

32. Can cuts in tires be mended?

33. What is the object of the studded tire?

34. What is the cause of side-slip?

35. What is meant by "camber of the road"?

36. Are there other ways of avoiding side-slip?

37. Are there other tires especially made to avoid side-slip?

38. Is it safe to run with a deflated tire?

39. Might not this injure the steel rim?

40. If a tire is so damaged that it will not hold the inner tube, or the inner tube is so damaged as to be useless, and a spare tube is not at hand, is there any way of using the casing to avoid running on the rim?

41. Is there not some arrangement to enable a car to run with a deflated tire?

42. Are solid tires often used?

STUDY HELPS.

Answers to Questions for Review.

NO. VIII.—TIRES.

1. The pneumatic tire is full of compressed air, and air is the most elastic substance known. In a solid rubber tire the pressure is on one point only, the point which bears on the ground. In a pneumatic tire the pressure is evenly distributed all round the circumference.

2. The outer cover, called the casing, and the inner tube into which the air is pumped; the casing strengthens the inner tube and takes the pressure off it.

3. The steel rim underlying the pneumatic has flanges on each side which are turned inwards; into these the bead of the tire is forced.

4. The thickened inner edges of the casing.

5. Yes, to a certain extent; but as motor tires are so much larger and heavier, a great deal more force is required to remove and replace them.

6. The wheel being jacked up clear of the ground, the inner side of the casing is levered over the outer flange, and pushed into the inside flange; then the tire bolts or security bolts are put in, and pushed up or outward; the outer edge or bead is levered into place with the tools provided for that purpose.

7. There are several forms of jack. The common form is a tubular stand of cast-iron or steel with a broad foot. Inside is a screw working in a nut at the top of the stand. When the nut is turned by a lever the screw is worked upward, and as the jack is placed under the axle the screw raises the wheel.

8. Bolts the heads of which are plates made to fit the inside of the casing; these hold the casings in place. If the

casings were only held by the rim there would be a possible danger of their being forced off when turning corners.

9. The inner tube, which must be dusted over with chalk, is inserted in the casing, the valve stem being first inserted in its hole, but without the valve. The inner tube is then put evenly in the casing without any twist. Care must be taken to see that it does not get under the heads of the bolts. The valve is then put in, and a little air pumped in, to see that it is in its right place; the outside bead, or edge of the casing, is levered in and worked round till it is in its right place, but before doing this the bolts must be pushed outward, so that the edge of the casing can get down into its place; then the bolts are pulled up into their places and tightened up with the wing nuts, and the tire is pumped up.

10. Yes; unless care is taken, the inner tube may get nipped, that is, twisted and folded back. A tube is likely to be injured at a fold. A tire bolt may nip the inner tube, and by squeezing it it may weaken it so that that part would be more likely to give out. A bolt may even cut the inner tube.

11. Chalk is used to prevent the inner tube sticking to the casing.

12. Pressure should vary with the weight of the car; about 60 lbs. per square inch in small cars, and 80 or 90 lbs. in large ones.

13. On some pumps there is a pressure gauge. A small gauge is sold to screw on the valve to show the pressure, but experience will tell how a tire is pumped.

14. If a tire is only partly inflated it will bulge out at the sides where it rests on the ground; it should be pumped till this bulge disappears.

15. It is likely to burst an old one; an old tire should not be pumped so hard as a new one.

16. The tire is deflated, the bolts loosened and pushed back, also the valve stem; the casing is levered over the steel rim, beginning near the valve stem, till it is clear of the rim

all round, the valve stem pushed back through its hole, and the inner tube taken out.

17. Having found the puncture either by putting the tube in water or by dusting with chalk, with a little air pressure in the tube, a patch—that is, a piece of rubber sold for the purpose—is taken, the inner tube being first rubbed with sandpaper all round the puncture.

18. To get fresh, clean rubber to hold the solution. Indiarubber solution will not adhere to old dirty rubber.

19. These are made of pure rubber; the edges are much thinner than the middle. Indiarubber solution, when applied to sheet rubber, causes it to swell, and the edges curl up; if the edges were not thinner it would be difficult to keep them down when applied to the tube.

20. It is smeared over with rubber solution, and exposed to the air till it is "tacky."

21. That the solution is getting thicker by the evaporation of the naphtha in which the rubber is dissolved, and is sticky and tenacious to the touch. It is then placed over the puncture and pressed down. A folded cloth, a piece of flat wood, and a weight of six or seven pounds should be put on it to press the patch home.

22. That depends on the quality of the solution and the temperature, also, probably, on the dryness of the air—perhaps from fifteen minutes to an hour. If a tube is not required immediately it is a good plan to let it remain six or eight hours under pressure.

23. Not very easily. Motorists should always have at least one spare inner tube—two or three are better.

24. Yes, a piece of indiarubber cut from a tobacco pouch, etc., but it must be well cleaned with sandpaper before being covered with the solution.

25. Yes; vulcanizing. This is done by heat, at a temperature of 315° F. This heat welds the rubber into a homogeneous mass.

26. A small steam boiler generates steam to a pressure of about 70 lbs., at which pressure the temperature of the steam is that above mentioned. This method is used also for mending casings that have been cut by stones, etc.

27. Some drivers have been known to carry them in the tool box, where they are exposed to the friction of the tools every time the tools are used. Oil and grease will then get on the tubes, to their injury, for oil and grease have a destructive effect on rubber. This is the worst place to carry the tubes, and often a tube, when required, may be found to have been injured. The best way is to carry tubes either in waterproof bags, or in a closed box lined with cloth or felt.

28. It is possible they would, but the expense would be considerable. These small wheels have great strength, owing to the shortness of the spokes.

29. A gaiter or sleeve can be laced on. This is made of leather or rubber, and greatly strengthens a weak part of the tire. Even a leather strap will often help a bad tire to get home for ten or twenty miles, or even more. There are also inner strengthening pieces made to go in the tire, which are held in place by the casing pressing on the metal rim of the wheel; they are slipped under the edge of the casing.

30. It can be strengthened by a piece of prepared canvas (this is stout canvas, one side coated with indiarubber) stuck inside. The inside of the casing is well cleaned with, preferably, gasolene and a wire brush; it is then coated with rubber solution. As the casing is porous, it will absorb two or three coats of the solution; each one must be allowed to dry before the next is applied. When the last one is tacky, the canvas, which has been cut to the right size, is rubbed well down, and should stick in the casing. The canvas should be large enough to come to the edges of the casing, so that the pressure of air in the tube should help to hold it in place. It should be 8 or 10 inches longer than the damaged part.

31. It can also be mended by vulcanizing.

32. To a certain extent they can; there are several adver-

tised preparations for filling cuts, and some of these are fairly effective.

33. To prevent side-slip steel studs are embedded in the fabric of the casing, especially on the tread or wearing surface of the tire.

34. First and chiefly, greasy roads, and sometimes careless driving, such as turning too quickly or applying the brakes suddenly. It is also caused by unequal weight on the driving wheels, either from passengers being chiefly on one side of the car, or the camber of the road being too great.

35. Most roads are higher in the middle than at the sides, to allow water to run off. If a car, where roads are slippery, gets to one side it may not recover itself, especially if the steering wheels are moved through a considerable angle.

36. Yes; various devices are used, including chains, which go across the tread of the wheel from circular chains on each side; the latter are very effectual.

37. Yes; some have rubber projections similar to the steel studs; others have raised rubber corrugations on the tread; others bosses with depressions in them all round the rim.

38. Running on a deflated tire would very likely ruin the casing, especially if the car were a heavy one. It would be preferable to take the tire off and run on the metal rim.

39. It might with a heavy car, but not with one of moderate weight, and for a short distance—eight or ten miles; but the car must be driven slowly. The steel rim will very likely be cut about and scratched by stones, and these scratches must be rubbed down with a file before the casing is replaced.

40. It can be filled with cotton waste if it can be obtained; failing that, hay, straw, or grass. This prevents the rims seriously damaging the casing, which they would otherwise do if the car were run with a deflated tire. The tire bolts must be removed and the car driven at a moderate pace.

41. Yes, a detachable wheel. It is a stout steel rim in which is carried a fully inflated tire. This wheel is clamped

on the defective car wheel, and the car runs on the detachable wheel.

42. Not at the present time, except on motor buggies and heavy trucks. The pneumatic tire has superseded them. A car with solid tires should have larger wheels than a pneumatic-tired car. Besides, the great advantage of the pneumatic is that it takes so much shock and vibration off the car and machinery that it prolongs their life.

STUDY HELPS.

Questions for Review.

No. IX.—TROUBLES.

1. What causes loss of compression?
2. What is the effect of lost compression?
3. How is compression regulated?
4. What is meant by valve setting?
5. Is perfect action of valves necessary?
6. How is faulty valve action made known?
7. What is a "knock"?
8. What causes a "knock"?
9. How may the trouble be overcome?
10. Is there any difference between a "knock" and a "pound"?
11. Describe the latter.
12. What causes misfiring?
13. What is the proper remedy?
14. What causes overheating?
15. Describe proper procedure in overheating.
16. What produces an objectionable noise in motor operation?
17. Is there any way of stopping this noise?
18. In case ignition fails how would you locate the cause?
19. What troubles are likely to occur in battery service?
20. In case batteries become exhausted how may they be temporarily recharged?
21. What causes objectionable odors?
22. What is the effect of leaks?
23. Is there any manner of overcoming these leaks?
24. What are the main causes of failure to start?
25. What causes a puffing noise in the exhaust?
26. What causes grating noise in the differential?
27. Is there any way of preventing a water-cooled motor from freezing?

28. What objection is there to the use of a common salt solution?
29. What is the objection to the use of calcium chloride?
30. Is there any reliable method of starting a motor without cranking?
31. In case carbon accumulates in the cylinders, how may it be overcome?
32. What are the principal causes of noises in transmission gears?
33. How may trouble in a timer be overcome?
34. What are valve tappets?
35. What condition of the tappets results in noisy valves?
36. How may this noise be eliminated?
37. What symptons indicate a flooding of the float chamber of the carbureter?
38. How may the trouble be remedied?
39. When an engine is hard to start what is usually the cause?
40. What steps should be taken to overcome it?
41. What is liable to cause the sudden stoppage of an engine?

STUDY HELPS.

Answers to Questions for Review.

No. IX.—TROUBLES.

1. Loss of compression may be caused by leaky valves, leaky piston rings, or breaks or cracks in the piston or cylinder. In testing for compression trouble operate the pistons by the hand crank—do not attempt to fire the motor. Apply a thick suds to all the joints in connection with the cylinder, and coat the outside with them. If there is a leak the air forced into the cylinder will form bubbles in the suds in escaping through the leak. If there are no bubbles the cylinder and joints are sound and the trouble is in the valves.

2. Loss of compression generally manifests itself in a hissing sound, and the motor is hard, or altogether impossible to start; the hand crank may be turned with little effort.

3. Leakage at the valves may be suppressed by putting a moderate pressure on the flange nuts or screwed caps. Should the valve seats be leaky they must be reground. Cracks in the cylinder can be overcome only by patching. Leaky piston rings call for new ones.

4. Valve setting is the regulation of the valve movement so it will act in exact unison with the ignition system.

5. Yes. Unless the valves act in perfect unison with the ignition spark there will be trouble.

6. By the failure of the engine to start. By diminished power. By loss of compression. By popping and misfires.

7. A "knock" is usually a sign that something is loose in the connections.

8. Something may be loose or broken. One frequent cause is the wearing out or loosening of the connecting rod or crankshaft bearings. A loose fly-wheel may also cause a knock. So may the melting out of the bearing linings.

9. This depends upon the cause of the trouble. If the parts are merely loose a tightening up will generally overcome the trouble. If the parts are worn out they must be replaced.

10. There is a great difference between "knocks" and "pounds." The former generally occur in connection with the crank case mechanism, while the latter are invariably found in the cylinder.

11. The word "pound" is descriptive. It is a dull pounding sound as distinguishable from a "knock," which is sharp and hard.

12. Short circuits in the wiring, or other battery connections. Battery exhausted. Coil defective. Dirty or faulty plug. Contact blades not making firm contact. Terminals loose or dirty. Broken or weak spring on striker arm of low tension magneto.

13. Test the ignition system by close examination until the cause of trouble is located. Then proceed accordingly. If short circuit, make proper connection; if dirty plug, clean it, etc.

14. There may be a defect in water circulation or imperfect radiation. Insufficient lubrication or poor oil is another cause. Engine running too fast, or cylinders misfiring will also cause overheating. Faulty carburetion is another cause.

15. First, stop the motor and allow it to cool. Replenish the radiator with cold water. See that both pump and fan are running fast. If there is insufficient lubrication, supply more oil. Should the carbureter give too much, or too rich a mixture, regulate it to furnish more air and less gasolene.

16. Frequently there is too much space between the ends of the valve stems and the tappet rods. These, being of metal, come together with a loud clicking noise, repeated at least 500 times per minute for each cylinder.

17. The only remedy is to readjust the valve stems so there will be not more than 1-32 of an inch clearance between them and the tappet rods.

18. By testing the wires to make sure there is no break or defect. This may be done by disconnecting them from the

spark plugs, and trying the exposed ends of the wire against the metal car frame. If there is a sharp, quick spark, the battery and wires are all right, and the trouble is undoubtedly in the plug. If there is no spark when the wire is touched to the frame, the trouble may be in the wire itself or a defective battery.

19. Wires broken so direct connection is lost, insulation chafed off so there is a leak, or the battery itself exhausted.

20. Punch a few holes in each cell with a common nail, and immerse the cells in a solution of sal-ammoniac for five minutes. This will recharge them so they will have energy enough to operate for some hours.

21. Burning too much lubricating oil, and using too rich a gasolene mixture.

22. Leaks in water supply result in overheating of motor. Leaks in gasolene tank result in failure of fuel to reach carbureter and consequent stoppage. Leaks in lubricating oil tank cause hot bearings.

23. There is no permanent relief aside from the soldering iron. A motorist caught on the road, however, may obtain temporary relief by patching the leaks with chewing gum, or bread paste, but these patches will soon soak off.

24. This may be due to faulty ignition, and this is generally the cause. In very cold weather the carbureter may be frozen.

25. Joint in exhaust pipe loose or faulty. Failure of muffler to work properly. Escape of compression.

26. Teeth of pinions or driving bevels may be stripped. Shaft bearings may want adjustment. Road wheels may require attention.

27. There are various chemical combinations such as alcohol and water, and even a common salt mixture which will prevent freezing. The most satisfactory, although the most expensive, is alcohol and water, because it does not affect the metal parts of the machine.

28. Salt will destroy the metal of the radiator by electrolytic action.

29. It must be chemically pure or there will be excessive corroding.

30. Not positively, but as a general thing, it can be done with 6-cylinder cars.

31. Give them a thorough cleansing, and wash them with kerosene.

32. Long shafts, loose ball bearings, and deformation of gears.

33. By fitting a steel spring to the commutator cover so as to ensure perfect contact.

34. Valve tappets are the upright rods which open and close the valves by working against the ends of the valve stems.

35. When the distance between the ends of the tappet rods and the ends of the valve stems is too great there is sure to be noise.

36. By readjusting the tappet rods so the clearance will not be more than 1-32 of an inch.

37. Slipping of clutch when ascending hill, and engine does not respond to cranking after a stop.

38. In most instances opening the pet cock under the carbureter and draining off some of the surplus gasolene will remedy the trouble.

39. Generally an excess of gasolene or lubricating oil in the explosion chambers.

40. Cut down the supplies of both gasolene and oil, and spark the cylinders until the excess is disposed of.

41. Almost always the cause of this trouble is defective ignition.

STUDY HELPS.

Questions for Review.

No. X.—TIMING AND VALVE SETTING.

1. How many valves are there on each automobile cylinder?
2. Name and describe them.
3. What is the usual form of automobile valves?
4. Describe a common trouble in timers.
5. How can it be remedied?
6. Is there a substitute for the ordinary switch plug?
7. What benefit, if any, is there in reversing the ignition current?
8. What is an auto-sparking device?
9. What is the Remy magneto system?
10. Name some of the common magneto troubles.
11. How may defective valves be remedied?
12. Describe the process of regrinding a valve.
13. When is the regrinding of a valve necessary?
14. What is meant by the setting of a valve?
15. How is the valve action to be timed?
16. What is the difference between a magneto and a dynamo?
17. What is the difference between a low-tension and a high-tension magneto?
18. What connection, if any, has the valve system with the ignition system?
19. What is meant by timing the ignition?
20. Describe process of resetting valves so as to obtain perfect action.
21. What benefit, if any, is there in having the valves work perfectly?
22. What is an induction coil?
23. Name a principal cause for the non-working of valves.
24. Describe the method by which valves are operated.
25. What relation does the valve mechanism bear to the motor?

STUDY HELPS.

Answers to Questions for Review.

No. X.—TIMING AND VALVE SETTING.

1. There are two, on the successful operation of which depends the satisfactory running of the motor.

2. The inlet and the exhaust. The former admits the charge of vaporized gasolene, and the latter gets rid of the residue of the gas after explosion.

3. Virtually all automobile valves are of what is known as the mushroom pattern. This refers to the shape of the valve head, which is slightly conical on top, and perfectly flat on the bottom so that it will rest securely and smoothly in its seat, thus preventing all intake or outlet of gases when closed.

4. The roller and contacts which produce the sparks necessary to secure ignition become rough from wear and the contact is imperfect. The rubber or fibre of the roller wears away faster than the metal contact makers, and this leaves a depression into which the roller drops, and then bounds off the contact without resting long enough to allow the coil vibrator time to act.

5. Try a new timer, or go over the wiring carefully, and also make sure that the platinum coil contacts are bright and filed even.

6. On most automobiles a Yale key, a nail, or any thin, flat strip of metal will answer for a switch plug when the latter is lost or mislaid. Insert this substitute between the spring contacts and exactly the same result will be produced as when a regular switch plug is used.

7. Constant use of the current in one direction tends to destroy the platinum contact points. Every time the current is interrupted or broken, a minute quantity of platinum is volatized, and carried across the gap to the opposite point. If the current is kept constantly working in one direction this

volatization in time wears out one of the points so that it is worthless. By reversing the current the process of volatization is equalized and both points kept in the same condition.

8. This is an automatic, self-regulating device, which ensures regular sparking, and thus produces regular ignition, provided the flow of fuel vapor is normal.

9. In the Remy system there is a dual ignition which makes sparking more certain, and tends to lessen the troubles in this line.

10. Lack of protection, poor wiring, inferior spark plugs, improper timing, lost motion in control system, open circuit, bad alignment, poor ground connections, unequal polar gaps, and static discharge of current.

11. By grinding. For complete description of this process see page —— in "Ignition, Timing and Valve Setting."

12. This process is too long to give in detail here. See reference as above.

13. When the head or seat of the valve has become worn so that it does not fit snugly and allows the gasolene vapor to escape before its force has been properly expended. This results in a loss of power and inability of the motor to perform its normal amount of work.

14. By making it work in perfect unison with the ignition. Unless this is done the results of the gasolene explosions attendant upon ignition will be unsatisfactory. The valves must be in a certain, definite position when the explosions occur, and the process of placing them in this position is called "setting."

15. The inlet valve should begin to open so as to admit a new charge of gas when the exhaust valve has closed. To make sure that this position is obtained turn the motor slowly by means of the hand crank until the piston of the front cylinder is at its highest point. Next turn the large pinion on the inlet camshaft to the left until the front inlet valve begins to lift from the seat. Now turn the exhaust valve camshaft in the same direction until the valve of the front cylinder is

closed. Now slide the small pinion along the crankshaft and into mesh with the teeth of the two large wheels, keeping the holes for the taper pin in exact line with that through the shaft, and making sure that the large hole in the pinion is at the same side as the larger end of the hole in the crankshaft.

16. In a magneto the electricity is generated by the action of magnets, while in the dynamo the electricity is produced by the conversion of a high degree of mechanical energy.

17. The high tension system is operated at a very high pressure or voltage, generally about 20,000 volts. This excessive voltage is used to force the current from the primary or battery circuit through an interrupter, which breaks it frequently and with great suddenness. Every time there is a "break" or interruption in the primary current, a secondary current arises, which is different from the primary in many ways, and which flows through an entirely distinct and separate circuit. It is claimed for the high-tension system that it produces a hotter, quicker and more reliable spark than it is possible to procure in the low-tension system.

18. While not directly connected mechanically, so far as automatic action is concerned, they must operate in unison, and with clock-like regularity. Thus, the ignition spark must be made and the explosion occur when the valves are in a certain position. If there is a minute fraction of a second difference, the force of the explosion is lost and the fuel wasted, and a dangerous back fire may result.

19. Timing the ignition is the regulation of the mechanism which controls the ignition spark so that the spark will be produced and the explosion occur at the proper time.

20. The answer given to Question No. 15 will meet the requirements in this case.

21. It is impossible to operate a motor satisfactorily unless the valve action is perfect. The force which propels the vehicle is obtained by a rapid succession of explosions on the piston heads in the various cylinders. Unless the inlet valve to each cylinder is tightly closed or "seated" when an explosion oc-

curs the expansion produced by the explosion is largely lost, and the propulsive force correspondingly diminished.

22. This is the apparatus by means of which the ignition spark is produced. No matter by what means the electric current may be originated, whether from battery, magneto or dynamo, the current itself does not produce the necessary spark unless there is an interruption in the flow at stated intervals. It is through the induction coil that the necessary spark is obtained.

23. Frequently the clearance space between the ends of the valve stems and the tappet rods becomes disarranged, leaving too large or too small a clearance. In either case the valve action will be faulty.

24. A tappet rod, working through a close-fitting guide, is raised and lowered about 1-32 of an inch some 500 times a minute by the revolutions of the camshaft. When raised, the end of this tappet rod lifts the end of the valve stem immediately above it, and the valve is opened. When the tappet rod drops, the valve is also lowered, the head falling back into the seating and closing the opening.

25. A motor without valves would be inert and lifeless. Even in the motors known as "valveless" there are openings and closings which are in reality valves, but which are operated without the ordinary valve stem and tappet rod mechanism. There must be some means of regulating the admission of fuel to the explosion chamber, and provision for the expulsion of the residue after explosion. This is secured by the use of valves of some sort.

STUDY HELPS.

Questions for Review.

No. XI.—MOTORS AND MECHANISM.

1. What improvements, if any, were made in automobile motors in 1910?
2. What objectionable feature is overcome by multiplicity of cylinders?
3. How is this result obtained?
4. What is meant by "tongue"?
5. Why is excessive vibration objectionable?
6. Describe a simple test for illustrating vibration.
7. Does multiplying the number of cylinders increase the speed of a car?
8. In what manner does a multiplicity of cylinders promote economy?
9. What particular advantage attaches to a six-cylinder car on high gear?
10. In what manner is lack of proper balance indicated?
11. Is there such a thing as a noiseless motor?
12. How is the noise eliminated?
13. What is an injection two-cycle motor?
14. What is a T-head motor?
15. In what manner does the Mann valve gear differ from that ordinarily used?
16. What beneficial results, if any, have been secured by English experiments in carbureter action?
17. How cheaply can a practical automobile be constructed?
18. Describe briefly the cheapest machine thus far made.
19. Who constructed this machine?
20. Is a three-wheel motor car practical?
21. To what extent has the three-wheel plan been adopted?

22. In what vital feature do the foreign models of 1911 differ from those of 1910?
23. What particular merit is claimed for the change?
24. What benefit is gained by having a long stroke and small bore?
25. In what respect does the change help motor car users financially?
26. What is the now generally accepted ratio of stroke to bore?
27. What effect is produced on the rated horse power?
28. What particular form of ignition now finds greatest favor?
29. What changes, if any, have been made in the lubrication system?
30. What is the result of these changes?
31. In what manner is a change being made in the action and design of carbureters?
32. What results have been accomplished in the use of benzine as a motor fuel?
33. How many miles can be made on a gallon of benzine with an ordinary 4-cylinder touring car carrying the usual load of four passengers and their baggage?
34. Allowing that benzine is available as a motor fuel, is its use more economical than that of gasolene?
35. How is the Pittsfield four-cylinder dash coil made?
36. What is the safety kick-off switch?
37. Describe the Type C. timer.
38. Why is the piston clearance sometimes made greater at the bottom than at the top?
39. Where may a "rattle" noise be looked for?
40. What does the Selden patent cover?
41. Is there a pneumatic tire which is airless?

STUDY HELPS.

Answers to Questions for Review.

No. XI.—MOTORS AND MECHANISM.

1. One of the most noticeable, and probably the most important, is the adoption by nearly all the standard concerns of six-cylinder models. A few years ago only one firm was making six-cylinder cars. Now nearly every firm of established reputation in the country is turning them out.

2. Principally the annoying jar and vibration incident to most machines of fewer cylinders. This vibration is greatest in the one-cylinder car, and diminishes as the number of cylinders is increased. Thus, it is less in a two-cylinder car than in a one; still less in a four-cylinder than in a two, and almost entirely eliminated in a six.

3. By securing practically continuous tongue. The explosions occur so rapidly that there is virtually no noticeable elapse of time between them, and consequently no opportunity for the mechanical hesitation which produces vibration.

4. Continuity or smoothness in engine rotation.

5. Because it tends to crystalize the metal parts of the machine, especially the steel in the frame and axles. It is a well-known fact among experts that the steel in a heavy locomotive run at high speed, becomes dangerous from crystalization, and is liable to fractures.

6. Place an automobile on a wooden floor and start the motor, changing it at times to the various speeds. Vibration will be distinctly noticeable in the shaking of the lamps, fenders, dash board, steering columns and control levers. The zone of speed at which this vibration will be most noticeable varies in the different makes of machines, but all of them will respond to greater or lesser extent at some stage of speed.

7. No. Unless the bore of the cylinders and the stroke of the pistons is increased, and provision made for increasing the revolutions of the crankshaft, the speed remains the same. But, multiplying the cylinders does increase the "power" in exactly the same proportion to the increase in cylinders. A four-cylinder machine will have double the power of a two-cylinder, provided the cylinders are of the same size, but not necessarily be any faster unless increased speed is gained by a change in the gearing.

8. By keeping down the cost of maintenance. It is asserted, and seems to be upheld by incontrovertible evidence, that it is cheaper to operate a six- than a four-cylinder car. One maker advocates that ten of his six-cylinders, under the supervision of their respective owners, ran a total of 65,687 miles in 1910, at a total upkeep expense of $15.13. This, of course, was exclusive of oil and fuel. It covered the expense of repairs.

9. It is possible to run much more slowly on a high gear, and still power enough stored up for use in case of emergency. Suppose the case of a car moving slowly, as is necessary in a crowded street, and the driver wishes to get ahead of some obstacle in front. A six-cylinder machine will always respond promptly in a case of this kind, and still be checked down immediately when the demand on its excess power is over.

10. Take the case of an old-fashioned foot-pedal grindstone. Start this in rapid motion, then suddenly take your foot off the pedal. It will almost tip over. This is due to lack of balance.

11. Yes. A motor made without mushroom valves, as is done in the Silent Knight, is practically noiseless.

12. Elimination of the mushroom valves removes the hammer effect of the meeting of the ends of the tappet rods and valve stems. Slide valves, which are noiseless, are substituted for the mushroom valves.

13. Read carefully the description of the motor perfected by A. E. Palmer, of Cleveland, Ohio, as given on page —— of Automobile Motors and Mechanism.

14. A motor with its cylinder head in the form of the capital letter T. The Pullman Company makes the claim that this arrangement allows of a greater expansion of the explosive gas, and consequently more power.

15. Simplicity, ease of operation, and readiness of access to the working parts in case of necessity.

16. Practically none, beyond the fact that most of the extra attachments placed on carbureters for regulating the flow of air are useless.

17. A practical working automobile, capable of making 15 miles an hour, has been constructed for $25.

18. It was made entirely of second-hand material. The frame consists of oak timbers with revolving steel shafts on which are babbited old bicycle wheels. The motor is a 2 h. p., two-cycle engine, capable of making 1,000 r. p. m. Transmission is by means of a chain enclosed in a garden hose which runs from the engine shaft to a pulley on the rear shaft.

19. Ralph W. Dunkle, of Greenville, Ohio, who constructed the car solely to demonstrate what could be done in this line.

20. Yes. It is made so by the use of a flexible underframe by which the tilting tendencies incident to former three-wheel cars are overcome.

21. Only one concern is thus far making three-wheel machines, but its product is meeting with ready sale, and it is probable the manufacture of cars of this design will be extended.

22. The bore of the cylinders is being made much smaller and the stroke of the piston considerably longer.

23. That it produces a greater horse power on a lessened consumption of fuel.

24. A general lightening of the motor weight per horse power actually produced.

25. In France and England especially the cost of government taxation is greatly reduced. In France the basis of taxation is the rated h. p. In England it is the size of the cylinder bore.

26. The stroke is, as a rule, about 1½ times greater than the bore. A few makers are doubling it.

27. Motors built on this plan and rated at 12 and 14 h. p. will develop an actual power of from 30 to 32.

28. High tension. The low tension form has been virtually abandoned.

29. Adoption of crank case pumps which deliver oil under pressure to the various bearings.

30. Economy in oil consumption, and a lessening of the smoky exhaust nuisance.

31. By providing for the admission of gasolene and air to the explosion chamber through different openings, instead of admitting them already mixed.

32. It has been demonstrated that benzine may be used in the same manner and with the same equipment as gasolene.

33. From 19 to 20 miles for each gallon of benzine.

34. Yes. Benzine, as now produced, in connection with the production of gasolene, is largely a waste product. At least it is produced in larger quantities than can be disposed of at what the makers think a fair price. Consequently it is sold at a lower price than gasolene, and is fully as effective as a power-producing fuel.

35. The units are made with primary and secondary windings and a condenser. These are so balanced that, taken in connection with the vibrator, only draw ½ ampere on a short circuit and 1-5 ampere when the engine is running. The spark coil is so arranged that the units are easily removed and are interchangeable, making a very neat and economical coil. These coils can also be made with hinged brackets. These are a convenience when used on an overhung dash, as the coil can be tipped forward to allow adjustments to be made, without disconnecting any of the wires.

36. This switch is equipped with a large lever and knob, allowing the operator to throw the lever with the toe, instead of bending to an uncomfortable position to reach it with the hand. The switch is also furnished with a switch key having two burrs at its contact end. These burrs lock in a fitted

groove at the back of switch; and by an ingenious arrangement of springs, contact cannot be made without the proper key, which makes it proof against meddlers. This switch is made for both double battery and magneto and battery systems.

37. The type "C" timer is of the old reliable roller type, but with original improvements. This timer has double ball bearings, one at each end of the base, preventing wobbling of the shaft and thereby destroying the accuracy of the timing. The method of holding the central contact lever in place is with a key on the shaft, which is threaded with a fine thread and fastened at the top with a castellated nut and cotter pin, and by turning this nut one groove, a play of about .005" is taken up, this allowing the timber to be kept free of lost motion. This timer also has a grooved roller, the advantage of which is to cut a track for itself in a contact surface; and with these sharp edges, effectually cutting through grease or any other obstruction, making a positive contact at all times.

38. The amount of expansion of cast iron from which pistons are made is 1:909 at 212 degrees Fahr., does not perceptibly affect the amount of clearance, but by having the top larger than the bottom lubricant is sucked up in the form of a cone with the apex towards the top and less likely to pass than if the apex was the other way as it would be if the bottom of the piston was larger than the top.

39. Look for this noise on either the fenders or running boards. As those are both of metal they often cause quite a rattle if the bolts fastening the fender to the running board are not tight.

40. The Selden patent covers the broad claim of running a vehicle by an internal combustion engine. This is about as simply as the matter can be stated. This patent was at first upheld by the United States circuit court, and all automobile makers who used gasoline motors without obtaining a license from the owners of the patents were declared infringers. A number of makers, however, declined to accept this ruling, and the decision of the court was appealed. The United States

circuit court of appeals has now reversed the former finding and the case has been remanded for retrial. It is a matter of great importance to automobile users as the final upholding or defeat of the patents means an eventual increase or decrease in the price of motors.

41. So-called. But it is pneumatic in appearance and resiliency only. To fill the demand for a tire that would have the wearing qualities of a solid (freedom from puncture and blowout) and the riding qualities of a pneumatic, especially in taxicab and motor wagon service, one company has developed an airless clincher tire. In outward appearance this tire is identical with the conventional pneumatic, but in interior construction it differs radically. In place of the air tube contained in the ordinary pneumatic tire the interior of the airless tire contains a large number of radial columns or supports about one inch and spaced about an equal distance apart. When the tire strikes a stone—when the vehicle is in motion—immediately all the weight of the wheel is carried on one, or not more than two, of the columns of rubber, which causes an abnormal expansion or bulging of the rubber to take up the depression of the tread caused by the stone, as shown in the accompanying engraving. The stone, therefore, becomes buried in the tire, just the same as in the pneumatic, but in the case of the latter air is displaced, while in the case of the airless tire rubber is displaced. When the wheel rolls over the stone the rubber immediately resumes its regular structural form.

STUDY HELPS.

Questions for Review.

No. XII.—DRIVING SELF TAUGHT.

1. What should a novice do before attempting to drive a car?
2. How should speeds be changed?
3. What relation does the clutch bear to speed?
4. Of what use are the control levers?
5. What is meant by gear changing?
6. How can you tell when gasolene is exhausted?
7. What should you do when the car "skids"?
8. When haulage is necessary how should tow line be attached?
9. What simple rules ensure best work of motor?
10. How may simple leaks be stopped?
11. What is the safest course in descending hills?
12. In meeting a nervous horse, or other animal, what should the motorist do?
13. In case of an involuntary stop how may trouble be located?
14. What occasions loss of power?
15. In case of tire deflation what should be done?
16. How may ordinary punctures be repaired?
17. Is trouble likely to occur in the carbureter?
18. In case it does, where is the trouble likely to be found?
19. How may faulty ignition from a battery system be remedied?
20. Is there any difference in the quality of gasolene?
21. To what extent does it affect operation of the car?
22. What is meant by "spark lever"?
23. How should a car be selected?
24. What is the transmission system?
25. Describe the various kinds of transmission.

26. What is the law of the road?
27. In what respect does the American law differ from the English?
28. What is reasonable care?
29. What is a chauffeur?
30. How may speed be made with security?
31. Is there any great amount of money in race driving?
32. What constitutes negligence in driving?

STUDY HELPS.

Answers to Questions for Review.

No. XII.—DRIVING SELF TAUGHT.

1. Become thoroughly acquainted with the mechanism of his car. Examine each part carefully while the car is in garage, and get an understanding as to what each part is intended to do, and the relation it bears to the general mechanism.

2. Slowly and carefully. Unless great care is used portions of the teeth may be "stripped," or chipped off. This will entail the buying of new gear wheels, or the making of expensive repairs. The act of changing gears properly requires a prompt, but delicate and sympathetic touch. An experienced hand can tell, even before the gears come into contact, whether he may proceed to enmesh them with safety.

3. It is the clutch which engages the gear mechanism, and starts the car. It is specially important in gear changing. When fully engaged the clutch ensures the highest speed; when released the car slows down. Proper handling of the clutch is an important item in successful driving. In no other way can a car be manipulated safely in crowded streets, or in descending hills.

4. These regulate the motor action. They control the change from low to high speed, and vice versa, and also the emergency brake action. By them the speed and movements of the car are absolutely controlled.

5. It is by this process, the engaging or releasing of the gears, that change is made from high to low speed, or vice versa.

6. Frequently by an utter stoppage of the motor. This is always the case when the gasolene tank runs dry. Gradual loss of motor power is also an indication that the gasolene

supply is running low, or that the carbureter action is clogged.

7. This is generally due to slippery or treacherous roads. If the car shows an inclination to slip to the right, steer the front wheels in the same direction. This will have a checking influence on the rear wheels. There is really no actual remedy. Chains, and other rough surfaces, are used on the rear wheels to prevent skidding, and with considerable success, but their action is not absolute. One safe plan is to stop the car the moment it shows an inclination to skid, start it very slowly and carefully across the road, and gradually bring it into the desired position, proceeding with extreme caution and slowness.

8. Avoid attaching the tow line to the front axle of the disabled car, as it brings too much strain upon the axle. It is better to secure the line to the projecting ends of the frame, making two connections and bringing these connecting ends together in one line a few feet back of the towing car. In this way the strain is divided. It not only is distributed equally, so far as stress on the extreme outside parts of the frame is concerned, but is also divided between the two axles. When the tow line is attached to the center of the front axle, as is often done through ignorance of the results, all the strain comes on the one spot and the axle is frequently bent or twisted. When a hitch must be made to the axle, make two connections, getting as close to the hubs in each case as possible.

9. Cleanliness of all parts, liberal lubrication, good gasolene, and regular ignition. This combination will generally ensure satisfactory action of the mechanism. But, even with these important features carefully looked after, brains must be used in the operation of the car, particularly in the handling of the various control levers. It is an easy matter to let too much gasolene into a cylinder, to flood the carbureter, to disarrange the ignition system, or to choke off lubrication by misuse of the control levers. Any one of these troubles will make it unpleasant for the driver.

10. French motorists—and they are generally more resourceful than the proverbial Yankee—seldom start on a trip without a good-sized piece of rye bread in the locker. Wheat bread will answer, but rye is much the best. In case of a leak the driver breaks off a bit of the bread, chews it slightly to moisten it, and then works it into a gummy paste by kneading it with his fingers. Drain off the leaky tank and wipe the outside of the leak dry. Then apply a good coating of the bread paste and allow it to harden thoroughly before refilling the tank. This will give temporary relief until a permanent repair can be made.

11. Go slow. Even if the grade is slight, proceed with caution. On steep hills it is the worst of folly to allow the car to run fast. It will gain such momentum that the driver will lose control of it, and it can not be checked with the brakes.

12. As a rule get past as quickly as possible. This can generally be done before the horse has a chance to become frightened. But in case the horse has seen the machine approaching, and is restive, the motorist should stop his car at once, shut off the motor so as to stop all noise, and give the horseman an opportunity to lead his steed past in safety.

13. Trouble of this kind is almost invariably due to motor failure of some kind. The cause may generally be located by the nature of the stoppage. If this is sudden the cause may be found in a broken battery wire, to a stuck valve, to obstruction in the carbureter, or to the seizing of a piston. If, on the other hand, the stoppage is gradual it is likely caused by a lack of gasolene, or lubricating oil, or to failure of compression. Where the stoppage is intermittent, look for a defective spark plug, or a nearly exhausted battery.

14. This is one of the most difficult of motor troubles to diagnose accurately. Unless located by chance it necessitates thorough examination of all the motor mechanism and its connections. Loss of power may be caused by weak batteries, disarranged timer, dirty spark plugs, defective magneto, foul

valves, weak valve springs, and many other mechanical defects. Insufficient gasolene supply, and lack of proper cooling will also cause loss of power.

15. Stop the car at once, and pump up the tire. Then locate the leak by putting spittle, or some similar moisture over the suspected part. The escaping air will form bubbles in the moisture. If the leak is caused by a puncture the tire must be deflated and a patch applied. If the leak is around the valve the latter must be tightened or replaced.

16. Deflate the tire and sandpaper the affected part so as to get a new, fresh surface. Cut a patch in oval form so as to be a little larger than the damaged part. Cover the under side of this patch with a coating of rubber cement and allow it to become partly dry. When in a thick, gummy state, apply a second coat. Then put the patch in place and hold it firmly until the cement adheres. Reinflate the tire slowly until it begins to assume a round, full form. At this stage wrap the patch with adhesive tape, or put on a patent "sleeve," and finish pumping up.

17. Not so frequently as most people think. Occasionally, but not often, trouble is caused by dirt getting into the gasolene, or by a leaky float.

18. Where there is a stoppage by dirt the obstruction will be found in the jet, and must be removed, either by air pressure or probing with a fine wire.

19. This is too complicated and important a subject to be satisfactorily covered in short space. See pages 92 to 100 in Ignition, Timing and Valve Setting.

20. Yes. There is a great difference in the quality of gasolene. The best is always the cheapest in the end, but it must be used sparingly.

21. Too rich a mixture, too much gasolene for the air supplied, will foul the cylinders and lead to a number of troubles such as overheating, pre-ignition, carbon deposits and knocking.

22. The spark lever is the mechanism by which the ignition

spark is advanced or retarded as may be desired. It is located on the steering wheel so as to be within handy reach of the driver.

23. With the one purpose of meeting the personal needs of the purchaser. Unless the buyer has an intimate knowledge of gasolene motors and car construction generally, the safest plan is to buy on reputation.

24. Transmission is the method by which the power generated in the motor is transferred to the driving wheels of the car, and the propulsive force utilized. The motor delivers its power to the crankshaft, causing the latter to revolve. From the crankshaft the transmission system "transmits" this power to the driving wheels in the rear, the wheels in front being left free of rigid connections so they may be used for steering purposes.

25. Primarily there are four—shaft, gear, chain and belt. These are in turn subdivided into many classes, each manufacturer having his own ideas as to the manner of applying the transmission, and, very naturally, claiming that his system is the best.

26. Under all possible circumstances to keep to the right and avoid crowding a party approaching from an opposite direction, even though that party is occupying more than one-half the road.

27. The American law says, "keep to the right." The English law says, "keep to the left."

28. This is determined solely by the conditions. What would be reasonable care at one time would be gross negligence at another.

29. A chauffeur is a person who drives a motor car for pay. The courts have ruled that drivers who do not receive pay are not chauffeurs.

30. By allowing the traffic to move freely without restraint in blocks, but insisting upon a slow-up or halt at crossings.

31. Not so much as generally supposed. The best paid driver earns about $20,000 a year. In aviation earnings of from

$40,000 up are common. The majority of racing automobile drivers do not earn over $10,000 a year.

32. Like reasonable care it depends upon conditions. The Michigan supreme court has held that a motorist who crossed to the wrong side of the road in attempting to avoid a collision, was guilty of gross negligence.

THE AUTOMOBILE POWER PLANT.

A BRIEF CATECHISM.

What is the source of power in modern motor cars?

The majority of cars are driven by what are termed internal combustion engines. Gas, oil, and gasolene engines are internal combustion engines.

Is a steam engine an internal combustion engine?

No. In a steam engine the combustion takes place outside the boiler, and at atmospheric pressure. The heat has to pass through the plates of the firebox, or through the metal of the tubes to reach the water. A large quantity of heat goes up the chimney, which is lost. In an internal combustion engine the heat is developed in the cylinder.

Is the action of an internal combustion engine similar to that of a steam engine?

No. Quite different. In a steam engine, steam is let into the cylinder at each end alternately, and drives the piston backward and forward.

What are meant by a piston and cylinder?

A cylinder is any circular object with parallel sides; a pencil is a cylinder; so is a lawn-roller; so is the barrel of a locomotive boiler; but, in speaking of machinery, a cylinder is a hollow casting, bored for its length truly circular and parallel, and this part is termed the bore, and in it the piston works steam-tight or gas-tight.

What is meant by combustion?

Burning. The oxygen of the air combines with various substances and produces heat. There are various speeds of

combustion; for instance, a hay stack will sometimes heat, and after some weeks take fire—this is very slow combustion. Charcoal placed in an open dish burns very slowly. Gunpowder and the modern high explosives burn very rapidly.

Is it possible to tell exactly how long the gas in a gasolene motor cylinder will take to burn?

Probably in less than one-hundredth part of a second.

How does an internal combustion engine, such as is used in motor cars, differ from a steam engine?

In most cases the air and gasolene vapor (often called the explosive mixture) are drawn into the cylinder by the outward movement of the piston; as the piston returns the mixture is compressed, then fired, when it drives out the piston, doing work; the piston returns and drives out the spent or exhaust gases, and then draws in a fresh mixture. So the cycle is as follows:

1st outstroke, sucking in mixture.
1st instroke, compressing.
2nd outstroke, firing, doing work.
2nd instroke, exhausting.

This is what is known as the Otto cycle. It was first introduced in practical gas engines by Dr. Otto, a German engineer.

How does this mixture get into the cylinder?

It is sucked in on the first outstroke, passing through the inlet valve; then, before the piston begins to return, this valve is closed, so that the mixture cannot escape, and it is compressed. When compressed it is fired, causing explosion, generally by an electric spark, and great heat is produced. The gases in the cylinder expand with the heat, forcing out the piston. When the piston has gone as far as it can—that is, to the end of its stroke—the exhaust valve is opened, and the burnt gas escapes into the air.

What is meant by the stroke of the piston?

The distance it travels in the cylinder.

Is there any definite proportion between the bore of a cylinder and the stroke of the piston?

No; but the stroke is generally longer. In a locomotive an 18-inch cylinder has a stroke of 24 or 26 inches. In very high-speed engines, such as motor car engines, the stroke is less in proportion to the bore.

How many revolutions each minute do motor car engines make?

From 1000 to 1200, sometimes more.

Why do they run so fast?

There is a limit of the speed at which pistons can travel, so it is better to have a short stroke and run the engine faster.

Is there any arrangement for opening the exhaust valve at the proper time.

Yes; it is opened by a cam or projection on a shaft, which only makes one revolution to two of the crank shaft.

What is a cam?

It is a projection very like a long big tooth in a cog-wheel.

How is the rotary motion of the engine obtained from the up-and-down motion of the piston?

By means of a crank and connecting rod.

Give an illustration of this.

A bicycle is propelled by the up-and-down motion of the rider's thighs and knees; the leg is like the connecting rod and presses on the cranks, converting the up-and-down motion into a rotary one.

Why does not the piston remain at the end of its stroke? What causes it to return?

On the crankshaft is a flywheel—that is, a heavy wheel, sometimes two wheels—which form part of the crank; the impetus of the flywheel carries the crank round, and forces back the piston.

What is meant by impetus?

Any body or substance when in motion has a tendency to go on; a ball thrown from the hand does not at once stop, but goes on for several yards according to the force with which it is thrown.

The flywheel, being pivoted at its center, tends to keep on revolving. Its momentum causes it to continue to revolve, pushing the piston backwards and forwards till its energy, or the power stored in it, is exhausted.

One side of the flywheel is thicker and heavier than the other: why is this?

It is made heavier to balance the weight of the crank and part of the connecting rod; the heavy part is opposite the crank. If the crank were not balanced, the engine would shake violently, and in time would very likely damage itself considerably. Balance weights can be noticed on the driving wheels of locomotives. The early locomotives had no balance weights, so they were unsteady and rolled sideways at high speed, and had a tendency to run off the line.

How are flywheels fixed to the crankshaft?

They are keyed on. A key in machinery is a piece of steel of square section which fits into a groove in the crankshaft for half its depth; the other half fits into a groove in the flywheel; the key is driven in tight to lock both the shaft and flywheel together. Frequently in small motors the end of the shaft is turned taper or conical in the lathe and the flywheel bored to exactly the same taper. The flywheel is

then forced on and the key driven in to hold the two together. A nut at the end of the shaft prevents the flywheel working loose.

Are all crankshafts made like this one?

No. Cranks are made out of the solid. A steel rod has the crank forged upon it, and it is cut out in the lathe, or by a special machine for cutting cranks.

Is any arrangement made to allow for wear in the piston and cylinder?

In the piston are three, sometimes four, rings, which are turned to a slightly larger diameter than the cylinder; a small piece is cut out of them, leaving an opening in the ring of about a quarter of an inch. They can then be squeezed so that they will enter the cylinder. By their elasticity, they press on the bore of the cylinder. They fit in grooves (turned out in the lathe) in the piston, and prevent the pressure passing the piston.

Why should there be three or four? Would not one do?

A little of the compressed gases, and of the pressure must pass where the ring is cut open. The escaped gas is checked by the next ring and very little passes it, so that an extremely small quantity, if any, will pass the third ring.

Is there any particular way of placing these rings in the grooves of the piston?

Yes. The gaps must not be in a line; they must be placed one-third round the piston from one another, so that explosive gas which may pass at the first gap has to travel one-third round the piston to get to the next gap.

What is to be done when rings get worn, and the piston is not tight?

They must be taken out and replaced with new ones. The

old ones must be sprung open by putting a pointed tool under one end of a ring and then working out the groove and pulling it off the piston. It is best to commence with the middle ring, for if an end ring is taken out first, No. 2 ring will probably slip into the empty groove. If, however, the piston is connected to the connecting rod and crank, and the gap of the ring will not open enough to pass the connecting rod, the ring nearest the connecting rod should be taken off first.

Is there anything particular in putting in new rings?

Yes. They must be tried in the cylinder first, for there may not be sufficient gap to allow them to close sufficiently to enter the cylinder. Then it should be seen that they are not too wide for the grooves. The top one should be put in first, then the second, then the third. They must be opened very carefully, as they are liable to break.

What metal are these rings made of?

Cast iron, of good quality.

Will cast iron spring sufficiently to allow rings to pass over the piston?

Yes; but as they are turned and bored, the hard and brittle skin of the casting has been cut away. The interior of a casting is less brittle than the skin.

Is their anything peculiar about the rings?

Yes. They are slightly thicker at the part opposite the gap; this gives a more uniform spring all over the ring.

What is the gudgeon or piston pin?

The pin in the piston which is embraced by the small end of the connecting rod.

What is the big end of the connecting rod?

The end that goes round the crank.

What is a crank pin?

The part of the crankshaft to which the connecting rod is attached.

Is there anything to prevent the piston pin getting loose?

Yes; there are various ways of keeping it tight. Sometimes a hole is drilled through that part of the piston which holds the gudgeon pin, and through the gudgeon pin itself, and a steel taper pin driven in. Sometimes the gudgeon pin is held tight by a set-screw, which pinches it.

What do you mean by a pin?

In machinery, any piece of round iron or steel coupling any two pieces of metal.

What is a split pin?

A pin made of half round wire. The wire is doubled back on itself, the flat sides together, so that in section it is circular but divided up in the middle; it is thus a pin split down its middle, hence the name. The ends of the wire are opened out so that it cannot work back through the hole it is inserted in.

What are split pins used for?

To keeps nuts from working loose on their bolts. A hole is drilled through the bolt just above the nut, the pin is pushed through and opened out. They are also used to keep certain parts of machinery in their proper places: to keep a wheel or a lever on the pin it is working on.

What is a set-screw?

A screw for keeping a wheel or collar, or any working part, on its shaft. A hole is drilled through the wheel or collar and tapped for a screw.

What do you mean by "tapped for a screw"?

A hole is drilled a little less than the size of the screw; a screw thread is cut in the hole by taps.

What are taps?

Hardened steel screws which are turned round by a wrench or spanner. They have cutting edges cut all up them, so that when inserted in a plain hole they cut a thread in it; in fact, making it a nut.

What is a collar?

Collars are of two sorts, movable and fixed. A movable collar is fixed on its shaft by a set-screw or key, or by a pin going right through collar and shaft. A fixed collar is a circular projection turned up on the shaft. Shafts usually have collars on them at the ends of the bearings, to prevent the shaft working sideways.

What is meant by bearings?

The place in which a shaft of any sort revolves. They are usually made of a different metal to the revolving shaft. Bearings are usually made of brass, or bronze, which is a harder and tougher description of brass. The bearing brasses are small and light, so that they can be replaced without much expense.

What are white-metal bearings?

Usually brass bearings lined with a soft metal—some alloy of tin. Hence they are called white-metal bearings, as tin is a white metal.

Have they any advantages over brass or bronze bearings?

Yes. They are not so likely to seize as brass.

What do you mean by "seize"?

If a bearing gets hot through defective lubrication the shaft and bearings expand, and such great friction is set up

that the shaft is at last gripped by the bearing and cannot revolve. Connecting rods and cranks have often been broken by seizing. A white-metal bearing will run or melt before seizing; the engine will then knock and give notice that something is wrong; the white-metal bearing is easily and inexpensively replaced. Bearings are usually in halves, so that wear can be taken up by the bearing bolts.

What is a bush or bushing?

A bearing that is not in halves. It is made of either steel or bronze; it is forced into a hole bored to receive it. When the bush is worn, it is knocked out and replaced with a new one. Bushes sometimes have a flange at one end to keep them from moving.

What are ball bearings?

Bearings in which hardened steel balls are placed between the moving shaft and the fixed bearing. They usually run on a hardened steel cone on the shaft, and a cup inserted in the boss of the revolving part. There are usually a pair of these bearings, one at each end of the revolving wheel or shaft.

What is a flange?

A flange is a projection round a wheel or any cylindrical object. Railroad wheels have flanges to keep them on the track. A pulley over which a rope runs has flanges on each side to keep the rope in its place. A pipe may have a flange cast or brazed on its end to couple it to another pipe.

Explain how the exhaust valve opens.

The shaft which carries the cam for lifting the exhaust valve revolves once for two revolutions of the crankshaft. On the crankshaft is a toothed wheel, which gears into another on the second shaft, sometimes called the half-time shaft. Now, the toothed wheel on the crankshaft having only half as many teeth as that on the second shaft, makes two

revolutions to one of the other shaft, for the exhaust has only to be opened once during two revolutions of the engine. A cam is a projection somewhat like a big tooth, and it is so geared relatively to the crank that it opens and closes the exhaust valve at the proper time. This second shaft also operates the electrical arrangement for firing the explosive mixture at the right time.

If the engine were taken to pieces for cleaning or repairs, would there be any difficulty in correctly replacing these two gear wheels, so that the exhaust should open correctly?

Yes; unless the wheels are set at the proper place, the engine would not work. The makers put a mark on each wheel, usually a dot made with a center punch, to show which teeth should engage, but if anyone has had any practical experience with gas or gasolene engines there is no difficulty in setting the exhaust valve. It must begin to open just before the piston reaches the end of the out-stroke, and close as the piston reaches the end of the in-stroke.

What is the exhaust valve like?

It is termed a mushroom valve, having rough resemblance to a mushroom. It consists of a circular plate termed the head, and from the underside of the head the stem projects downward. The valve fits down on its seating; to keep it tight a spiral spring surrounds the stem, the upper part bearing against the underside of the valve chamber. The lower part rests on a collar, which is kept in place by a cotter passing through a hole in the lower part of the exhaust valve stem.

What is a cotter?

It is a flat piece of iron or steel used for securing another piece of metal to a round rod.

Why should it be flat and not round?

A round cotter would not be strong enough; it would break

across unless it were of considerable diameter. A hole large enough for this would be too large for the valve stem, which would be very liable to break with a big hole through it. There is also a projection on the cotter which fits right up into the collar, and the collar holds the cotter in place, so that it cannot work out. The collar must fit down to rest on the shoulders of the cotter.

Do not exhaust valves leak after running for some time?

Yes; the valve has to be ground in with emery. The first thing is to remove the valve. In the head of the valve is a slot for a screwdriver. To grind in the valve the seat is smeared with emery powder and oil, and returned to its place and turned round on its seating by a screwdriver, working it backward and forward, and occasionally lifting the valve to allow the grains of emery to find fresh places. Emery and oil must be renewed from time to time, till valve and valve seating are either bright or of a gray color all round; then the emery must be carefully wiped out before the valve is replaced.

May not the emery get into the cylinder?

Yes, it is quite possible for it to do so. A good plan is to put a piece of cotton waste in the port or hole leading to the cylinder, but its removal must not be forgotten.

Is there any particular care required in replacing the valve?

Yes. To see that the stem is quite clean, and that the cotter is in its right place in the valve stem, so that the collar bears only on the shoulders of the cotter.

Are there any other methods of securing the exhaust valve with collar than by a cotter, as described?

Yes; sometimes the cotter is a plain piece of steel, and a split pin keeps it in place. Some exhaust valves are screwed at their ends and a nut pressed up against the collar;

a pin goes through nut and valve stem to keep the nut from getting loose.

Does the inlet valve require grinding in as often as the exhaust valve?

No. It is not exposed to so great a heat.

What causes the inlet valve to shut?

It is kept closed by a spring, and as the piston moves out, causing a reduction in the air pressure in the cylinder, the weight of the atmosphere moves the valve, and air and gasolene vapor come in. When the cylinder is full the valve is closed by its spring. These valves, worked by atmospheric pressure, are termed automatic valves.

Is there any other form of inlet valve?

Yes. Mechanically opened valves, that is, inlet valves opened by mechanism somewhat similar to that which operates the exhaust valve. These are now in common use.

Which is the best arrangement?

It is claimed that more power is given out by an engine with mechanically opened valves. The mechanically opened valve adds to the cost of the engine. If the spring of an automatically opening valve is properly proportioned there is but little difference.

Why is it necessary to start an internal combustion engine by hand? Why cannot it be started by opening a valve, like a steam engine?

The mixture of air and gasolene must first be drawn into the cylinder, then compressed by the return of the piston before it is fired. A four-cylinder engine will start on the switch; that is, when the electricity is turned on. In a four or more cylindered engine one cylinder will be standing, most

likely, with some compressed gases in it; but the gases must be got in first, either by the engine having the electric current cut off to previously stop it, when the cylinders will have some gas left in them, or by the engine being turned by hand to draw gases in before the electric current is switched on.

Why should air be drawn in with gasolene vapor?

To support combustion. A fire will not burn without air, neither will gasolene vapor burn or explode by itself.

Why is this?

Air is a mixture of oxygen and nitrogen. Oxygen alone will support combustion. The air is also useful to suck in the gasolene, which comes up in the form of a spray.

Why is the mixture compressed?

The mixture would give little power if not compressed. In the early gas engines (till Otto introduced the modern engine) the mixtures were not compressed, so the engines gave but little power, and were expensive to work.

How can you show that compression gives more power?

If a little gunpowder is placed on a slate or brick and fired, it goes off with a puff, giving out no useful energy; but if that gunpowder is put in a gun with an ounce or more of shot or a bullet on it, it will drive out the shot or bullet with great force, for directly the powder is fired the gases cannot escape on all sides as they did when the powder was fired in the open air, but the gases are confined by the barrel of the gun and the weight of the shot, and exert all their force in driving the shot up the barrel and for a great distance beyond.

What is the compression cock for?

It is to release compression when turning the engine round by hand for cleaning, and for adjusting sparking, for some

engines are very hard to turn against compression. It is also useful for oiling the piston; if the piston is stiff, which sometimes happens, kerosene is injected by the compression to make it work more easily.

What is gasolene?

Gasolene is distilled from crude petroleum. The word "petroleum" means rock oil. It is obtained by boring to the rock-bearing strata in certain parts of the United States and of Canada, at Baku on the Caspian Sea, in Burma, Rumania, and other places.

How is gasolene obtained from the crude oil?

The crude oil is placed in retorts and heated. The lighter portions are distilled off first, of which gasolene forms a small proportion. Then the heavier oils come off, such as kerosene, which is used for lamps; this comprises nearly half the bulk of the crude oil. Then heavy lubricating oils; then paraffin wax, used for making candles.

What is meant by heavier and lighter oils? and how is the weight of oil ascertained?

Oils vary in weight. The weight can be ascertained by taking a given quantity, such as a gallon, and weighing with weights and scales, but the best way is by means of a hydrometer.

What is a hydrometer? What does the word mean?

It means "water-measure." The word comes from the Greek. It is a glass tube or brass bulb weighted at its lower end, which, when placed in a fluid, floats higher or lower according to the weight of the fluid. It has a scale on it and it sinks to the mark 1.00 when placed in fresh water. If placed in sea-water it does not sink so deeply.

Why is this?

Because sea-water contains salt in solution, and is there-

fore heavier. If it is placed in kerosene it sinks deeper, oil being lighter than water. In kerosene it sinks to 0.80 or 0.82. This shows that kerosene is about one-fifth lighter than water. If it is placed in gasolene it sinks more deeply still, showing a mark of 0.70 or 0.72. If it is placed in ether, a very volatile fluid, it would sink lower and read 0.65.

Is there any practical use of this instrument for motorists?

Yes. Motorists when touring should carry a small hydrometer (sometimes called a densimeter) to test the specific gravity of gasolene offered at the various garages.

What do you mean by specific gravity?

Specific gravity is the weight of any substance compared to the weight of water, water being always taken as 1. Aluminum, which is the lightest metal used in mechanical arts, is little more than 2½ times the weight of water, its specific gravity being 2.56; cast iron is 7.22, or about 7¼ times heavier than water; wrought iron 7.69; steel 7.85; brass 8.1; copper 8.8; lead 11.4.

How does the hydrometer help the motorist?

Gasolene that has a greater specific gravity than .730 is very difficult to use in ordinary cars; it does not evaporate so quickly as it should, and gives less power.

How is the gasolene turned into a spray?

By means of the carbureter.

What is a carbureter, and what does its name imply?

The word "carbureter" means an apparatus by which the air is carbureted—that is, charged with carbon, or carbon and hydrogen—so that it will burn. In the older fashioned carbureters a true spray was not formed—the volatile gasolene was absorbed by the air passing over its surface; hence these carbureters were called surface carbureters; but there were

many objections to their use, and they have been almost entirely superseded by the spray carbureter.

Describe a carbureter.

A typical form of carbureter consists of two chambers; in one is a float so arranged as to keep the gasolene at a uniform level, in the same manner as the ball valve in house cisterns keeps them full of water. From this chamber, termed the float chamber, gasolene passes to the spray chamber; in this the gasolene passes up a vertical tube with a very small nozzle. The float is so arranged that when engine is not working the gasolene is just level with, or below the level of the nozzle, or jet, as it is termed. Now, when the piston sucks in air, the air flows past the jet and draws in a certain quantity of gasolene, forming a spray and carbonizing the air, which passes on to the cylinder and there does work.

What is the size of the opening in the jet?

It varies in different cars according to the power of the engine; on small engines it is about the size of a large sewing-needle.

Is not so small a hole easily choked with dirt in the gasolene?

Yes; although there is generally a strainer in the gasolene pipe these jets will often choke.

Cannot a carbureter be made that will be less liable to choke?

Yes; in carbureters of the Longuemare type the upright pipe is larger and closed with what might be termed a mushroom valve; this is screwed down tight so as to entirely close the opening, but to allow gasolene to pass, fine slots are cut or filed in the valve. These vary in number from eight to twelve, so it is almost impossible to get them all choked. The so-called mushroom valve is unscrewed by means of a

square on its top on which a spanner can be placed; it can be removed, cleaned, and replaced in a few minutes.

Is there any other advantage of this type of carbureter?

Yes; if the engine gets more gasolene than is necessary, it is easy to close one or more of the slots with solder.

What means is there of regulating the speed of the engine?

The speed is regulated by means of a throttle, which is a disk fitted in the inlet pipe, which can be turned through an angle to close the inlet pipe, the disk being the same size as the interior diameter of the pipe. The throttle is turned by a lever outside the pipe. This is worked by hand or by the governor. Some throttles are made of a piston working in a short cylinder.

What is the action of the float in the float chamber?

The gasolene enters by a pipe at center and bottom. This is closed by a rod, the lower end acting as a valve; the upper part passes through the cover of the float chamber. The float is cylindrical, or rather ring-shaped; it floats round this rod, but by means of two little levers it lifts the rod when the gasolene gets too low, and admits more.

If the float were to leak, what would happen?

The carbureter would get flooded; gasolene would run over and get lost on the road; the engine would get too much gasolene and work badly.

What is to be done if the float leaks on the road?

The best thing is to partially close the cock on the gasolene supply pipe, and to give the engine as much air as it will take. The float must be repaired as soon as possible.

How is this done?

First, the gasolene must be got out of the float. If the float

is immersed in very hot water, the gasolene will evaporate and bubble out of the hole. The hole is then closed with solder, which any tinsmith can do. If hot water will not cause the gasolene to come out, owing to the leak being extremely small, a hole must be drilled in it, the gasolene shaken out and the hole soldered up.

What is meant by flooding a carbureter?

Raising the valve so as to get an excess of gasolene for starting the engine.

What is a governor?

It consists of two weights—masses of metal—which are pivoted to a cross-piece fixed on a revolving shaft, generally an extension of the two-to-one gear. A spring keeps these weights near to the shaft, but when they are revolving at a considerable speed they fly away from the shaft—that is, from the center of their revolution—by centrifugal force. The weights are connected by rods and levers with the throttle valve, which they close or nearly close when the engine is running very fast. The governor is controlled by a spring, which has greater or less pressure put on it either by the driver's hand or by the action of his foot pressing on a pedal called the accelerator, so that the car can run at the speed desired by the driver.

How is the mixture in the cylinder fired?

By means of an electric spark.

Is an electric spark very hot?

Yes. An electric spark is formed by the heat it produces burning up some very minute particles of the metal from which the spark comes. The heat, although very intense, is so little in quantity that one cannot feel the heat by putting one's fingers close to the spark.

What is a spark plug?

A plug made of porcelain or mica, or some non-conductor of electricity. It is incased in a metal sheath, which screws into the cylinder; a wire passes through the length of the porcelain; the inner end of the wire is bent over to nearly touch the sheath, or a wire fixed in it. It is here that the spark is formed; this is called the sparking gap. The other end of the wire is connected to the high-tension wire or secondary of the coil.

What is the size of the sparking gap?

A little under one-sixteenth of an inch seems a proper size.

Why are spark plugs made of porcelain, etc.?

Because it is a non-conductor of electricity.

What do you mean by a non-conductor?

An insulating material. The cones on telegraph posts that carry the wires are made of porcelain; they are termed insulators, for electricity cannot pass through them.

What is the meaning of the word "insulator"?

This word is applied to any substance electricity will not pass through. The word comes from the Latin word "insula," an island, which is cut off from the land by the sea; so the insulator cuts off the electricity from any metals or conductors.

Are all metals conductors of electricity?

Yes. Copper is a very good conductor, hence copper, although it is very expensive, is used for submarine cables and for electric light purposes; iron is not nearly so good a conductor.

Mention some substances that are non-conductors.

Glass, indiarubber, gutta-percha, ebonite, vulcanized fiber, paraffin wax, dried wood.

Is water a conductor of electricity?

Yes; though to a far less extent than metals, hence it is necessary electrical apparatus should be kept from damp. Rain falling on a coil will, if the terminals are exposed, often stop a car running.

Are all fluids conductors of electricity?

Most acids are conductors of electricity. If sulphuric acid is added to water it greatly increases its conducting power. Oils are non-conductors.

How is the electricity used on cars generally produced?

It comes from a storage battery or accumulators, but a storage battery does not of itself produce electricity; it has to be charged from a dynamo or other primary source.

Describe a storage battery.

It consists of plates of lead either coated with, or holding in holes in the plates, certain salts of lead; they are placed in dilute sulphuric acid, and absorb the current from the dynamo, and when desired these plates can be made to give up their charge.

Is there any difference in the plates?

Yes; they are positive and negative.

Is it necessary to know which is which?

Yes; for charging the positive must be connected to the positive of the dynamo, the negative to negative.

How can you tell the plates apart?

The positive is generally marked red with paint or acid-resisting varnish, or a cross (+) is marked on it.

But if the paint be worn off and the cross not visible, is it possible to tell which is positive and which is negative?

Yes; unless the plates are so sealed up in their box that

they cannot be seen. Storage batteries have an odd number of plates, therefore the outside plates are negative. In a five-plate cell they would be negative, positive, negative, positive, negative. Besides this the positive plates are, with use, changed to a different color—a chocolate or reddish-brown; the negative a gray or slate color.

How many storage cells are generally used on a car?

Two.

Why?

In order to get the voltage necessary to work the coil; coils as now made require four volts to work them.

Explain what is meant by voltage?

It is an expression which shows what is termed the electromotive force, or pressure of electricity; each storage cell works at two volts, therefore two must be used for the coil.

How can you tell what voltage the cells give?

With a voltmeter, a small instrument consisting of a coil of wire and a bar of iron; when the current goes through the coil it pulls on the iron, and the strength of the current is shown on a dial.

Do storage batteries always give the same voltage?

No, not quite; when fully charged the voltmeter may read as much as 4.4 volts; after use the current may drop as low as 3.8, when they should be recharged.

How often do they require recharging?

This depends on the capacity of the cells and the distance run. Say four hundred to eight hundred miles. Batteries will also run down if left unused for some weeks.

If the battery runs down on the road and the car stops, what can be done?

The motorist should carry a spare battery with him. A battery may run down from various causes—damp or some electrical defect in the cell itself. If he has no spare storage cell he must procure at the nearest town a dry battery. This contains certain chemicals, but he must be certain that it gives sufficient voltage to run his coil. Some of these dry cells will run a car 700 miles, but by that time they are exhausted.

Can they be recharged?

No; they are then quite useless.

Describe a coil.

A coil consists of a bundle of iron wires surrounded by a coil of copper wire. Through this the current from the battery passes. This is called the primary wire. Round this, and well insulated from it, often by paraffin wax, is the secondary or high-tension wire, which is of very much greater length than the primary, but is much thinner wire.

But how does this give a spark?

When any electric current is broken a spark is produced, but if the current is passed through a coil of wire a much brighter spark is produced, and if the first coil be surrounded with a coil of longer wire a spark is produced in this, the secondary, or high-tension wire, which will leap through a considerable distance of air.

How is the electric contact broken to give the spark?

It is very similar to an electric bell, which, when the iron in the magnet is magnetized by the current going round it, attracts its armature or keeper, which carries the bell hammer. Now, as soon as the armature is attracted by the magnet it breaks the electric circuit and falls back again, then renews the circuit, and so goes on all the time the bell is

ringing. In a coil a small piece of iron, attached to a spring which forms part of the electric circuit, is attracted by the iron core in the center of the coil. This spring abuts against a screw which also is in circuit, so when the magnetism pulls the small piece of iron it breaks circuit and loses its magnetism, and the spring flies back.

Is there anything peculiar about this spring and screw?

Yes; they are tipped with platinum.

Why platinum? Is not platinum a very expensive metal?

Yes, it is more expensive than gold; but it is the only metal which will withstand the action of an electric current as a contact breaker, as this part of a coil is called.

Do platinum points wear forever?

No; after some time they become pitted; that is, holes or depressions appear on one side, and corresponding excrescences appear on the other. These must be filed away with a watchmaker's file, and the points adjusted by means of the screw.

How can you tell if a coil is working properly?

By the buzz of the contact maker; it should give a loud, deep note. Experience only will tell one the correct note.

Is there anything else in a coil?

Yes; what is termed a condenser. It consists of a number of sheets of tinfoil insulated from each other. The alternate sheets are connected to each side of the contact breaker.

How does it work?

It suppresses the bright spark at the platinum points and increases the spark in the secondary.

How are the wires coupled up on a car?

One wire from the coil is fixed to some metallic part of the car; the wire from the other terminal goes to the battery; from the other battery terminal it goes to the switch, where current can be broken to stop the engine, then from the switch to the contact breaker on the engine, where it passes to the metal work of the car, so completing the circuit.

What is the contact breaker on an engine?

The simplest form is a cylinder or drum of some insulating material, generally vulcanized fiber. It is fixed to the half-time shaft. In this is inserted a metallic plate flush with the circumference. This metallic plate is connected with some metallic part of the engine. On this fiber drum a spring presses, which spring is in the electric circuit; it is carried by a pear-shaped plate of ebonite, and so arranged that it can rotate a few degrees. The object of this is that electric contact must take place later when starting the engine and running more slowly than it does when the engine is running at full speed.

How is this done?

From the narrow end of the pear-shaped plate a rod is led to within reach of the driver, who can move it into any position he may require.

How is the secondary wire connected?

This wire goes from the insulated terminal of the coil, which can be known by an ebonite disk around it, to the spark plug. The other end of the secondary is generally connected in the coil to the terminal of the primary wire, which goes to the body of the car. This wire is sometimes called the ground wire.

Why is it so called?

The term comes from telegraphy, where plates buried in

the damp ground form the return circuit, thus saving the expense of a return wire.

How can you tell if the spark is passing at the spark gap?

By taking out the plug and putting it on some metallic part of the car, when the spark is seen.

Is this an infallible method?

No. If the porcelain is cracked the spark may pass through the crack, for when compression comes on a spark does not so readily pass through the compressed gases as in the open air, so it takes a short circuit through the crack in the porcelain.

If the spark fails to ignite the mixture, what is to be done?

Replace it with another.

Do these spark plugs ever require attention?

Yes; soot will be found on them. The electric current goes through the soot instead of giving a spark; this shows that the engine has either too much lubricating oil, or too much gasolene.

How is the spark plug fixed in the engine?

It is screwed into a hole in the cylinder.

Is there any possibility of compression leaking out at this screwed hole?

Yes; but to keep the joint tight a ring made of copper and asbestos is often used. This ring is squeezed tight by the shoulder on the plug when it is screwed in.

How can you tell if the joint is tight?

When the engine is running, by putting, with a small brush or syringe, a little kerosene round the ring; if it is not tight, bubbles will appear.

What can you do if it is not tight?

Screw it in further. If this does not stop it, put on a new ring, or even two, for the plug may be tight in the hole and so will not screw in as far as it should.

At what part of the stroke does firing take place?

Some time before the piston arrives at the end of its compression stroke. The explosion is not instantaneous with the contact breaker making the electrical connection.

If an engine were running slowly, might not explosion take place too soon?

Yes; it would cause the engine to knock, so the driver retards the spark; that is, causes the engine to fire later.

Is the spark retarded when starting the engine?

Yes. If it were not so the engine would fly backward, and the starting handle might injure the starter's arm or hand. Arms have been injured and even broken by this.

Is starting an engine dangerous?

No; but the driver should look and see if the sparking handle is retarded. Even if the engine flies back, no harm can be done if the handle is held carefully.

How should this be done?

The best rule is to pull, not push, against compression, and to pull up towards the shoulder; the hand should not grasp the starting handle, but the fingers should be hooked under it, the thumb turned away from the handle; if the engine flies back, the fingers straighten out and lose their hold on the handle. Of course the legs must be kept clear of the swing of the handle.

In a two, four or six-cylinder car, how is the contact maker arranged?

It is now usual to have a separate coil for each cylinder.

The contact is made in many cases by a roller or spring, which revolves inside a case, making contact with four or more metal plates connected with the different coils. Some of these contact makers are arranged horizontally, so that the working part runs in oil. Some four-cylinder cars have one coil, and what is termed a high-tension distributer.

Are there any other methods of firing the mixture besides the battery and coil?

Yes; the magneto system.

What is a magneto?

It is best explained in this way: As an electric current produces magnetism in an iron bar surrounded with wire, so a magnet will produce electricity in any coil of wire that is in motion round it. In a low tension magneto a coil of wire surrounds a soft iron armature, which, when it is caused to revolve rapidly close to the poles of a magnet, creates an electric current in the wire. The revolving armature is driven from the engine generally by gearing or a light chain; it produces a powerful current, but this current, not being of such high tension as that of the secondary produced by a coil, cannot jump across a spark gap, therefore a contact breaker has to be provided in the cylinder. This gives a good spark, and what is termed a flaming spark. High-tension magnetos are also much used. They produce a high-tension current similar to that produced by a coil, and the ordinary spark plug is used.

How is the engine lubricated?

Usually by what is known as the splash system. The crank case contains a certain quantity of oil—what is known as heavy or thick oil. It is most important that the oil should be of the proper quality. This oil in cold weather is nearly as thick as molasses, but it is soon warmed up in the crank case; the crank and connecting rods dip in the oil, and by their rapid revolutions splash it round and up into the cylinder, lubricating the piston and piston pin.

How can one be sure it does this? One cannot see into the crank case or cylinder.

No; but when an engine using such a system is taken to pieces the whole of the working parts are found covered with oil.

How is this oil renewed?

Either by a pump or by drop-feed lubricators, which drop the oil through short glass tubes, where it can be seen dropping. It is conducted by pipes to the cylinders, and also to other working parts of the engine and car. Some engines are lubricated by air or exhaust pressure on the surface of the oil in the oil tank, the pressure forcing the oil to the bearings, etc. Force-pumps worked by the engine are also used.

Do not the pistons, cylinders and valves get very hot in working, and is not this heat injurious to the machinery?

Yes; so hot that it is necessary to cool the engine in some way.

How is cooling effected?

In motorcycles and a few motor car engines the cylinder is cast with a number of plates, flanges or pins standing out all round it. These draw the heat away from the bore of the cylinder, and the current of air passing between the flanges or pins cools them and keeps the cylinder moderately cool.

How is the cooling effected in other cars?

In the majority of cars the cylinder is cooled by the water-jacket. A space is cast round the cylinder, through which water can circulate, and also round the valves as well. The circulation is usually maintained by a pump drawing water from a tank in some part of the car and forcing water through the cylinder jackets, then through the radiator, where it is cooled, and then back to the tank.

What is the radiator, and what is its object?

The radiator is for cooling the water after it leaves the cylinders. Its common form is a long length of pipe bent backwards and forwards. It is fixed in front of the car. On the pipe are soldered plates or grills, which, taking up the heat from the hot pipe, are cooled by the current of air the car meets in running.

Why are the plates soldered on?

If they were not in actual metallic contact with the pipe they would not so readily draw the heat from the pipe.

Are there other forms of radiator?

Yes; for example, the "honeycomb," so called from a fancied resemblance to a piece of honeycomb. It is a flat tank placed vertically in front of the car, through which a great number of small horizontal tubes pass; the current of air through these tubes is accelerated by a fan driven by the engine. The fan is placed close behind the radiator.

How is the water circulated through the jackets of the cylinders and through the radiator?

Usually by what is termed a centrifugal pump; it has vanes or paddles, which revolve and drive the water from the center to the circumference of the case in which it revolves—hence the name. The water is led in at the center, and goes off by a pipe at the circumference. This pipe leads off at a tangent from the case.

What turns the pump?

It is driven by the engine. There are several methods of driving it, usually by gearing, or a friction wheel on the pump spindle bears on a rim of the flywheel. The spindle passes through a stuffing box, so that water cannot escape.

What do you mean by a friction wheel?

A wheel with a flat rim made of leather or fiber, or even

hard wood. This is pressed up against the rim of the flywheel, and the friction causes it to revolve.

What do you mean by a stuffing box?

It is a cylindrical space round any revolving spindle (or round a rod having a backward and forward motion). The stuffing box is filled with packing, such as cotton, hemp, or asbestos. The cover is screwed on to keep the packing in place; it prevents water passing the rod. Steam engines have stuffing boxes on their front cylinder covers, through which the piston-rod passes, so that steam does not blow through.

Are there other methods of driving the pump?

Yes, several. It is often driven from the two-to-one shaft; it is sometimes coupled to this by a spring. In some cars it is driven by a chain.

Does the water boil away?

Not usually, if the radiator is properly proportioned to the size of the engine, or unless the car is going slowly up a long, steep hill, or in very hot weather, or is running with a wind behind it, and at about the speed of the wind.

Have all cars circulating pumps?

No; some cars are fitted with natural circulation, on the same principle that the hot water circulates in a domestic heating system. Hot water, being lighter than cold, rises, and travels to the cooler parts of the circuit. For natural circulation pipes must be much larger than when a pump is used, as the circulation is much slower.

Does the boiling of the water in any way affect the running of the engine?

Yes; the engine gets very hot and loses power. The cylinders get so hot that the incoming air is so heated that the proper weight of air cannot get in—for air doubles its bulk at about 500° F. compared with freezing point.

Does the temperature of the air in any way affect the running of the car?

The temperature does not affect it so much as the moisture in the air. In damp weather water vapor enters with the air and cools the explosive gases, so that less force is exerted on the piston. On a cold frosty day, when all the moisture of the air has fallen as snow or white frost, an engine generally runs at its best; also in warmer summer weather, when everything is dry.

What is the effect of frost on this large quantity of water in the car?

If the water in the cylinder jackets became frozen it would probably crack the jackets, and it might be necessary to get new cylinders.

How can this best be avoided?

The best way is to warm the motor house with heating pipes, the fire being outside the motor house. No fire should on any account be in the motor house, for if there were a leak of gasolene the car and house might be burnt up. Another way is to empty jackets, radiator and pump at night. Various anti-freezing solutions, of glycerine, etc., can be used in cold weather. Glycerine, however, is injurious to rubber.

Is the radiator likely to freeze when running in cold weather?

Not if the car is in motion, but if the car is stopped for even half an hour in the open, it is advisable to protect the radiator with a rug or similar covering.

If the radiator is frozen, what happens?

The water cannot circulate, the engine gets too hot and knocks violently, the mixture exploding not from the spark but from the hot metal of the cylinder.

What can be done in such a case?

The radiator must be thawed. The best plan is to pour hot water over it. But if hot water cannot be obtained, it can be thawed by burning oiled waste, paper, or anything at hand under it; but this should not be done unless the carbureter is some distance from the radiator. The gasolene supply cock should be shut to prevent any gasolene reaching the carbureter while there is any flame near it.

What indiarubber is there that could be injured by the glycerine in a circulation system?

The water connections are often made with a few feet of rubber piping for connecting the various pipes; if the pipes were all metal and rigid, the vibration of the engine would loosen the joints and give trouble.

How is the rubber tubing secured?

It is slipped over the metal pipes and bound tightly on with copper wire, or with brass clips made for that purpose.

What is meant by the "bonnet" of an engine?

The sheet metal cover that is placed over and incloses it.

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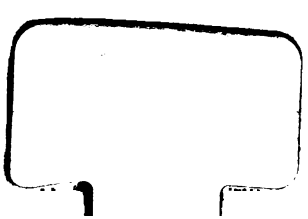
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